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FORM PTO-1390 (REV. 12-2001)

U S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY 'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see 37 CFR 1.5

10/089369

INTERNATIONAL APPLICATION NO. PCT/DE 00/03210

INTERNATIONAL FILING DATE September 14, 2000

PRIORITY DATE CLAIMED

TITLE OF INVENTION Representation of Emotions in Electronic Devices

APPLICANT(S) FOR DO/EO/US Alfred SCHURMANN

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [ ] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is attached hereto (required only if not communicated by the International Bureau).
   b. [ ] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [X] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [X] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [X] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [X] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [ ] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [X] Other items or information: a) Statement claiming small entity status, b) Request for amendment, c) English translation of the PCT request, d) Verification of translation, e) Credit Card Payment Form PTO-2038.

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U.S. APPLICATION NO (if known, see 37 CFR 1.5) 10/089369	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER

21. [X] The following fees are submitted:

				CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**					
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**					
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**					
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**					
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	- 20 =		x **$18.00**	$ 0.0	
Independent claims	- 3 =		x **$84.00**	$ 0.0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$280.00**	$	
TOTAL OF ABOVE CALCULATIONS =				$ 890.00	
[X] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. +				$ 445.00	
SUBTOTAL =				$ 445.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 445.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 445.00	
				Amount to be refunded:	$
				charged:	$

a. [ ] A check in the amount of $ __________ to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. __________ in the amount of $ __________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [ ] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. __________. A duplicate copy of this sheet is enclosed.

d. [X] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

A. Schurmann
SIGNATURE

Alfred Schurmann
NAME

____
REGISTRATION NUMBER

10/089369
JC13 Rec'd PCT/PTO 28 MAR 2002

Alfred Schurmann

Date March 19, 2002

international application No.: **PCT/DE00/03210** ; internat. filing date: Sept. 14, 2000
Title of the invention: Representation of Emotions in Electronic Devices

Assistant Commissioner for Patents, Box PCT
Washington, D.C. 20231

Request for amendment of all claims and Sect. 7.1 of the Description

Explanation of the amendment of all claims

The entire set of claims is amended as follows:
Amended claims: Amended claims 1, 2, 3, 4 and 5 are a new version of the entire set of claims. There are the following relations between the amended claims and the old ones:
Claim 1 (amended) formulates in a new way the main content of Claim 1.
Claim 2 (amended) formulates in a new way: (i) the first four sentences in Claim 1 (i.e. the content of lines 4, 5, 6 and 7), (ii) Claim 8 and Claim 9.
Claim 3 (amended) formulates in a new way Claim 2, Claim 5, Claim 7 and Claim 11.
Claim 4 (amended) formulates in a new way Claim 3, Claim 4, Claim 6 and Claim 10.
Claim 5 (amended) formulates in a new way Claim 12.

The reason for the amendment. The formulations of the claims in my international application are not clear enough. The new version of claims better state: (i) the consistency of the method described in my application, (ii) that said method is an engineering one, applicable in electronic devices, e.g. in a computer or a robot. The new claims do not go beyond the disclosure of the description.

Explanation of the amendment of Sect. 7.1

In the marked up version of amended Section 7.1 the changes relative to the previous version are marked by: underlining abcdefghij for added matter, 61 for changes of value.

Changes in Section 7.1: (a) a new condition for envy is given, in line 806; (b) intensities *bef(Pm,bnd(b),ta)* and *des(Pm,bnd(b),ta)* are determined by new formulae; thus lines 809, 810, and 811, in the old version, are replaced by lines 810, 811 and 812, in the amended Section 7.1.

The reason for the amendment. Section 7.1 is amended because the conditions for envy given in the previous version are not sufficient clear. The determination of intensity of envy (*bef(Pm,bnd(b),ta)* and *des(Pm,bnd(b),ta)*) is better described by formulae given in the amended Section 7.1.

Signature
A. Schurmann

Date March 19, 2002

I have attached:
- amended claims,
- amended Section 7.1,
- marked up version of amended Section 7.1

e) said intensity of fear is determined by said intensity of stimulus of an object, a situation or an activity;

f) said intensity of envy of a real or virtual human, *Pm*, at a success or a property of a real or virtual human, *P1*, is determined by: (i) intensities of satisfactions (*bef(Pm,b,t)* in the Description) and desires (*des(Pm,b,t)* in the Description) of said *Pm*, with respect to need *b*, for each need *b* connected with said success or property of *P1*; (ii) intensities of satisfactions of said *P1*, which are too great according to said *Pm*, with respect to said needs *b*.

Claim 3 (amended). What is claimed is:

Said, in Claim 1 (b), method for determining intensities of emotions: (i) contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering, with respect to a need *b*; (ii) frustration, depression, sadness and shame; comprising:

a) said intensities of contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering, with respect to a need *b*, at time *t*, of said (in Claim 2) *Pd*, are given by function values (*zful(Pd,b,t)*, in the Description) which are determined by: (i) said, in Claim 2, intensities of satisfaction and desire, with respect to said need *b*, perceived by said *Pd*; (ii) said, in Claim 2, stimulus patterns, with respect to said need *b*, which occur in descriptions (models) of objects, situations or activities, or which are associated with a goal;

b) said intensities of frustration and depression of said *Pd* are determined by said function values (*zful(Pd,b,t)*, in the Description);

c) said intensity of sadness of said *Pd* is determined by: (i) said function values (*zful(Pd,b,t)*, in the Description); (ii) said, in Claim 2, intensities of stimuli of objects, situations or activities; (iii) stimulus patterns associated with goals;

d) said intensity of shame of said *Pd* is determined by said function values, with respect to the need, *AN*, ´for recognition, acknowledgment and self-esteem` (*zful(Pd,AN,t)*, in the Description).

Claim 4 (amended). What is claimed is:

Said, in Claim 1 (c), method for determining intensities of positive emotions (liking, affection, love) and negative emotions (dislike, aversion, anger, hate, desire for retaliation and revenge, jealousy) to/for/of *OSA*, where *OSA* denotes an object, a situation or an activity; comprising:

a) said intensity of positive emotions of said (in Claim 2) *Pd* to/for said *OSA*, at time *t*, is given by first function values (*zulieb(Pd,OSA,t)*, in the Description); said intensities of dislike, annoyance, aversion and anger of said (in Claim 2) *Pd* to/for said *OSA*, at time *t*, are given by second function values (*abhas(Pd,OSA,t)*, in the Description); said first and second function values (*zulieb(Pd,OSA,t)* and *abhas(Pd,OSA,t)* in the Description) are determined by: (i) perceived said (in Claim 2) intensities of satisfactions and desires, with respect to need *b*; (ii)

said, in Claim 2, stimulus patterns with respect to need *b*, which occur in said *OSA* or are connected with a goal;

b) said intensity of desire for retaliation and revenge of said (in Claim 2) *Pd* on an object, *Ob*, is determined by changes of: (i) said intensity of dislike, annoyance, aversion and anger of said *Pd* to/for said object *Ob* (*abhas(Pd,Ob,t)*, in the Description); (ii) said intensity of positive emotions of said *Pd* to/for said object *Ob* (*zulieb(Pd,Ob,t)*, in the Description);

c) said intensity of hate of said *Pd* to an object, *Ob*, is determined by: (i) said intensity of dislike, annoyance, aversion and anger of said *Pd* to/for said object *Ob* (*abhas(Pd,Ob,t)*, in the Description); (ii) said intensity of desire for retaliation and revenge of said *Pd* on said object *Ob;*

d) said intensity of jealousy of said *Pd* of an object, *Of*, because of kind feeling or love of an *Pd1* towards said object *Of* (where *Pd1* denotes a human, a mammal, a virtual human or mammal in a software system, or an agent system), is determined by intensities of positive emotions of: said *Pd* towards said *Pd1*, said *Pd1* towards said *Of.*

Claim 5 (amended). What is claimed is:

Said, in Claim 1 (d), method for determining the intensity of feeling guilt, comprising:

a) said intensity of feeling guilt of said (in Claim 2) *Pd*, with regard to an object *PO*, is determined by: (i) decrease of said, in Claim 2, intensities of satisfactions of said object *PO* with respect to some needs *b* (decrease of *bef(PO,b,t)*, in the Description); (ii) decrease of said, in Claim 3, intensity of contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering of said *Pd*, with respect to the need *(AN)* 'for recognition, acknowledgment and self-esteem' (decrease of *zful(Pd,AN,t)*, in the Description); (iii) said, in Claim 4, intensities of positive emotions (liking, affection, love) and negative emotions (dislike, annoyance, aversion, anger) of said *Pd* to/for said object *PO* (*zulieb(Pd,PO,t)* and *abhas(Pd,PO,t)*, respectively - in the Description).

Alfred Schurmann; Date: March 19, 2002

International application No.: **PCT/DE00/03210** ; internat. filing date: Sept. 14, 2000

Amended Section 7.1 of the Description of *Representation of Emotions in Electronic Devices.*

7.1. Envy

A success or a property of a human, $P1$, can be the envy of another human, Pm. A success of $P1$ means an increase of $bef(P1,b1,.)$ for at least one $b1$. A property of $P1$ arises envy of Pm when Pm thinks that $bef(P1,b2,.)$ should be smaller, where $b2$ is associated with this property. Thus, we may define envy more precisely as follows: A human Pm envies human $P1$ his/her success or property, at time ta, when Pm believes that:

* $bfm(P1,b,ta) \geq cn(b) + bef(Pm,b,ta)$, for at least one $b \in Bd(Pm)$, where Pm thinks that the value $bef(P1,b,ta)$ equals $bfm(P1,b,ta)$ and $cn(b) \geq 0$;
* Pm thinks that $P1$ has no right to such great value $bfm(P1,b,ta)$;
* $des(Pm,b,ta) > 2$.

With this envy of Pm is connected the following need of Pm:

$bnd(b)$ - $P1$ should have such value $bfm(P1,b,t)$ that $bfm(P1,b,t) < cn(b) + bef(Pm,b,t)$, for $t > ta$. The intensity of the envy of Pm at the value $bfm(P1,b,ta)$ is described by $bef(Pm,bnd(b),ta)$ and $des(Pm,bnd(b),ta)$ as follows:

$$bef(Pm,bnd(b),ta) = min(18, max(-18, (bef(Pm,b,ta) + cn(b) - bfm(P1,b,ta)) * sqrt(des(Pm,b,ta)) /c2 + 6)),$$

$$des(Pm,bnd(b),ta) = min(50, max(0, ch1 * (bfm(P1,b,ta) - cn(b) - bef(Pm,b,ta)) * sqrt(des(Pm,b,ta)) /c2)),$$

where $1 < ch1 < 2$, $1.5 < c2 < 5$ (sugg.: $ch1 = 1.4$, $c2 = 2.5$).

Alfred Schurmann Date March 19, 2002

International application No.: **PCT/DE00/03210** ; internat. filing date: Sept. 14, 2000

The marked up version of **amended Section 7.1** of the Description of *Representation of Emotions in Electronic Devices.* The changes relative to the previous version are marked by: underlining abcdefghij for added matter, 61 for changes of value.

7.1. Envy

A success or a property of a human, $P1$, can be the envy of another human, Pm. A success of $P1$ means an increase of $bef(P1,b1,.)$ for at least one $b1$. A property of $P1$ arises envy of Pm when Pm thinks that $bef(P1,b2,.)$ should be smaller, where $b2$ is associated with this property. Thus, we may define envy more precisely as follows: A human Pm envies human $P1$ his/her success or property, at time ta, when Pm believes that:

* $bfm(P1,b,ta) \geq cn(b) + bef(Pm,b,ta)$, for at least one $b \in Bd(Pm)$, where Pm thinks that the value $bef(P1,b,ta)$ equals $bfm(P1,b,ta)$ and $cn(b) \geq 0$;
* Pm thinks that $P1$ has no right to such great value $bfm(P1,b,ta)$;
* $des(Pm,b,ta) \geq 2$.

With this envy of Pm is connected the following need of Pm:

$bnd(b)$ - $P1$ should have such value $bfm(P1,b,t)$ that $bfm(P1,b,t) < cn(b) + bef(Pm,b,t)$, for $t > ta$. The intensity of the envy of Pm at the value $bfm(P1,b,ta)$ is described by $bef(Pm,bnd(b),ta)$ and $des(Pm,bnd(b),ta)$ as follows:

$$bef(Pm,bnd(b),ta) = min(18,\ max(-18,\ (bef(Pm,b,ta) + cn(b) - bfm(P1,b,ta))*sqrt(des(Pm,b,ta))\ /c2 + 6)),$$

$$des(Pm,bnd(b),ta) = min(50,\ max(0,\ ch1*(bfm(P1,b,ta) - cn(b) - bef(Pm,b,ta))*\ sqrt(des(Pm,b,ta))\ /c2)\ ),$$

where $1 < ch1 < 2$, $1.5 \leq c2 \leq 5$ (sugg.: $ch1 = 1.4$, $c2 = 2.5$).

Alfred Schurmann

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International application No. : **PCT/ DE00/ 03210;** International filing date: Sept. 14, 2000

Assistant Commissioner for Patents, Box PCT
Washington, D.C. 20231
USA

VERIFICATION OF TRANSLATION

I Alfred SCHURMANN ,
Wuermersheimer-Str. 21
D -76448 Durmersheim
Germany
hereby declare that I am the translator of the above mentioned application and certify that the following is a true translation to the best of my knowledge and belief.

A. Schurmann
Signature of translator

Dated this March 19, 2002

Description

Representation of Emotions in Electronic Devices

Schurmann Alfred

1. Introduction

Computer scientist are concerned with representation of emotions in electronic devices since several years. I know the following papers (patents) which concern the representation of emotions in electronic devices. Padgham & Taylor [PTA] (1997), Breese & Ball [BRD] (1999), Brush & at all [BDL] (1998), Clynes [CLY] (1996), Kawamoto & Omura [KAO] (1994), Knight & at all [KMS] (1997), Skelly [SKE] (2000), Tow [TOW] (2000). In these papers, emotions are modelled in other way than below and not sufficient. The representation of emotions given in this description is based on notions (desires and satisfaction, stimuli) introduced in my papers [AS1] (1998) and [AS2] (1998). The representation of emotion states, given below, enables very good simulation of emotions:

a) In Internet and entertainment software - one may represent virtual people who behave emotional, according to the changing surrounding, and understand emotions of other virtual people, e.g. a virtual man in Internet who expresses emotions when he shows ware.

b) In agent systems which handle and communicate with people. Such agent system could not only express emotions according to actual situations but also understand emotions of people in surroundings of the agent system

These applications can be made if also other problems are solved, e.g. perception which can identify emotions, connection of behaviors with emotion states.

In this paper, the following stimulus and emotion states are formal described:

- the stimuli of *OSA*, where *OSA* denotes an object, a situation or an activity;
- contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, sadness, pain and suffering;
- positive feelings (liking, affection, love) and negative feelings (dislike, anger) to/for *OSA*;
- satisfaction and joy when a goal (goal situation) is achieved; dissatisfaction, anger and disappointment when a goal situation is not achieved;
- retaliation and revenge on an object, hate to an object;
- frustration, depression, sadness, envy, jealousy, shame and feeling guilt

2. Representation of Desires and Patterns of Stimuli

2.1. Desire and Satisfaction

In this description, *Pd* denotes a human, a mammal, a virtual human or mammal in a software system, or an agent system which simulates emotions. *Pd* has a set *Bd(Pd)* of needs. For a person *P*, *Bd(P)* contains the following

primary needs: *SN* - for tasty food, *EN* - for relaxation, *LU* - to breathe, *BW* - for bodily activities, *LE* - to be alive, *GE* - to be healthy, *KS* - to have no pain, *GR* - to belong to a community, *NU* - to be in normal environment with regard to temperature, smell, light, humidity, space and acoustics, *SH* - for visual beauty, *LI* - to be loved, *BN* - to take care over own children, *MA* - to have power over people or animals, *SE* - for sexual relations, *AN* - for recognition, acknowledgment and self-esteem, *NE* - curiosity and the need for identification, *MU* - for music. A human has also secondary needs, for example: $bvr(P1)$ - need for revenge on person $P1$, $bsz(Sz)$ - need to achieve goal situation Sz. An agent system (e.g. an artificial servant) may have the following needs: *GR* - to belong to a community, *ES* - for (electric) energy, *NG* - not to act against members of the community to which the agent belongs.

We describe the state of tension (desire) and satisfaction (relief) of a need b of Pd, at time t, by two functions:

$$0 \leq des(Pd,b,t) \leq 60, \quad -30 \leq bef(Pd,b,t) \leq 30, \quad \text{for } b \text{ in } Bd(Pd)$$

where $des(Pd,b,t)$ is the value (the intensity) of desire of need b and $bef(Pd,b,t)$ is the value (the intensity) of satisfaction or dissatisfaction of need b, at time t. These functions have the following properties:

i. Increasing function $bef(Pd,b,t)$ means Pd is satisfying his need b (positive stimulus) and is perceived by Pd with approval, pleasure, joy or happiness.

ii. When $bef(Pd,b,t) < 0$ and does not increase then Pd perceives $bef(Pd,b,t)$ as a negative stimulus with disappointment, disapproval, annoyance, anger, sadness or suffering, with regard to need b. Decreasing $bef(Pd,b,t) < 0$ means stronger negative stimulus with regard to b.

iii. If $bef(Pd,b,t) < 0$ then $des(Pd,b,t) > 0.1$. When $bef(Pd,b,t) < 0$ and decreases then $des(Pd,b,t)$ increases. $bef(Pd,b,t)$ and $des(Pd,b,t)$ can increase at the same time, for some needs b.

iv. $des(Pd,b,t)$ is the intensity of the desire of Pd to satisfy the need b at time t. The greater $des(Pd,b,t)$ the greater is the desire of Pd to satisfy the need b. $des(Pd,b,t) \leq 0.5$ means 'the need b of Pd is well satisfied at time t'.

v. The greater $des(Pd,b,t)$, the greater is the approval and joy of Pd when $bef(Pd,b,t)$ increases, and the greater is the dissatisfaction, the anger and the grief of Pd when $bef(Pd,b,t) < 0$ and decreases.

Example 2.0. vP is a virtual person in an entertainment software. It simulates the eating behavior of a man and takes three meals a day. vP had breakfast before 8.00. It has lunch in the time *1.00 - 1.30 pm*. The functions $bef(vP,SN,t)$ and $des(vP,SN,t)$ for that case are shown below

\ $t=$	8.0	8.3	9.0	9.3	10.0	10.3	11.0	11.3	12.0	12.3	1.0	1.05	1.10	1.15	1.20	1.25	1.30
$bef(vP,SN,t)$	4	3.5	2.9	2.3	1.6	0.9	0.2	-1	-1.9	-2.8	-3.6	-3	-2.3	-0.9	0.5	2	3.7
$des(vP,SN,t)$	1	1.4	1.9	2.3	2.9	3.5	4.1	4.8	5.6	6.6	7.7	7.1	6	4.8	3.7	2.4	1.3

2.2. Representation of Stimuli

We assume that *Pd* has models of objects and situations of his environment. *Pd* has also models (or schemes) of activities (behaviors, operations, procedures) which he/she can execute. When *Pd* perceives a new object, *On*, or a situation, *Sn*, then *Pd* creates a model for *On* or *Sn*. In the process of perception of actual objects, situations and activities (before their execution) *Pd* builds inner representations of these objects, situations and activities by the mentioned models. In this description, by an object, a situation or activity, *OSA*, we mean this inner representation of a real object, a real situation or a real activity. These inner representations have the same structures as the models of objects, situations or activities. Therefore, *OSA* denotes also the model of an object, a situation or an activity.

In *OSA*, stimuli are represented by values of functions *bef(Pd,b,t)* and *des(Pd,b,t)* as follows (the stimulus patterns given in Schurmann [AS1] and [AS2] are not sufficient):

('ds'; ([° | (Nba,Nb),] fs(Pd,b) = ([° | p;] n; (y1,z1),...,(yn,zn); q ht) [° | /[° | *z*] *eu*] [° |; *OSA1.Ej*] [° |; where *C*]); ...)

where [*tex1* | ... | *texk*] denotes one of the words *tex1,...,texk*, ° denotes the empty word, *Nba, Na, n* are natural numbers, $Nba \leq Nb$, $1 \leq n \leq 10$, *fs* denotes one of the patterns defined below, $0 \leq p \leq 1$, $-30 \leq yi \leq 30$, $-55 \leq zi \leq 60$, *yi* and *zi* are simple arithmetical expressions, *q ht* denotes a period of time (e.g. *20 min, 0.5 h, 4 h, 3 days, 1 week*), $n * q\ ht \leq 720\ h$, $z > 0$, *eu* denotes a measure (e.g. *kg, g, h, km, m, l*) and e g. */200 g* denotes *pro 200 g*.

((Nba,Nb), fs(Pd,b) = ...) means that the property *fs(Pd,b)* = ... holds *Nba* times per *Nb* applications (perceptions) of *OSA* by *Pd*. *Nba/Nb* is interpreted by *Pd* as the probability that the property *fs(Pd,b)* = . . holds. Example: *(80,120), fs(Pd,b) = (...)* in a situation *S* means: when *Pd* perceives this situation then he/she expects that *bef(Pd,b,.)* and *des(Pd,b,.)* alter, with probability *80/120 = 2/3*, as given by *fs(Pd,b)* =.... *C* is a condition If *C* occurs then the pattern *fs(Pd,b)* = ... may be applied only if *C* is true. If *OSA1.Ej* occurs then the pattern *fs(Pd,b)* = ... in *OSA* is connected with the pattern *Ej = ('ds',... fse(Pd,b) = (...)...)* in *OSA1*.

Now we define the patterns denoted by *fs*. We assume that *ds* property *fs(Pd,b)* = ... occurs in *OSA*.

fs = epb *epb(Pd,b) = (n; (y1,z1),...,(yn,zn); q ht)* [° | /[° | *z*] *eu*]

where $yn > 1 + y1$ and $z1 > 1 + zn$. The Meaning: Case: *OSA* is an object or a situation. *Pd* can execute (time *ta*) an activity, *AV*, such that when *Pd* uses *OSA* in *AV* then *Pd* expects that *OSA* will alter *bef(Pd,b,t)* and *des(Pd,b,t)* as given in (1). Case: *OSA* is an activity. When *Pd* executes *OSA* correctly then *Pd* expects the following function values:

$$bef(Pd,b,ta+(i-1)*q\ ht) = yi + dby, \text{ if } y1 > bef(Pd,b,ta)$$

$$= yi, \text{ if } y1 \leq bef(Pd,b,ta) \leq yi$$

$$(1) \qquad = bef(Pd,b,ta), \text{ if } y1 \leq bef(Pd,b,ta) \geq yi$$

$$des(Pd,b,ta+(i-1)*q\ ht) = zi + dbz, \text{ if } des(Pd,b,ta) > z1$$
$$= zi, \text{ if } zi \leq des(Pd,b,ta) \leq z1$$
$$= des(Pd,b,ta), \text{ if } z1 \geq des(Pd,b,ta) \leq zi, \quad \text{for } i = 1,\dots,n,$$

where $dby = bef(Pd,b,ta) - y1$ (< 0), $dbz = des(Pd,b,ta) - z1$ (> 0) and $y2\text{-}y1 + \ldots + yn\text{-}y1 > 0$. Below, in *Pr11* and *Pr12*, is given more exactly how we apply these formulae:

Pr11: Case: neither *'/z eu'* nor *'/ eu'* occurs in ***epb***, where *'/eu'* means *'/1 eu'*. In the following we write ***bef(b,t)*** and ***des(b,t)*** instead of ***bef(Pd,b,t)*** and ***des(Pd,b,t)***.

if $bef(b,ta) \geq y1$ then begin for $i := 2$ to n do $bef(b,ta+(i-1)*q\ ht) := max(yi,bef(b,ta));\ t1 := ta$ end
else begin $t1 := ta$;
while $y1 > bef(b,t1)$ do begin $dby := bef(b,t1) - y1$;
for $i := 2$ to n do $bef(b,t1+(i-1)*q\ ht) := yi + dby;\ t1 := t1 + (n-1)*q\ ht$ end;
$t11 := t1;\ i := 2$;
while $yi < bef(b,t1) \wedge i \leq n$ do begin $i := i+1;\ t11 := t11 - 1$ end;
if $i \leq n$ then for $j := i$ to n do $bef(b,t11+(j-1)*q\ ht) := yj$;
$t1 := t11$ end.

if $des(b,ta) \leq z1$ then begin for $i := 2$ to n do $des(b,ta+(i-1)*q\ ht) := min(zi,des(b,ta));\ t2 := ta$ end
else begin $t2 := ta$;
while $z1 < des(b,ta)$ do begin $dbz := des(b,t2) - z1$;
for $i := 2$ to n do $des(b,t2+(i-1)*q\ ht) := zi + dbz;\ t2 := t2 + (n-1)*q\ ht$ end;
$t21 := t2;\ i := 2$;
while $zi > des(b,t2) \wedge i \leq n$ do begin $i := i+1;\ t21 := t21 - 1$ end;
if $i \leq n$ then for $j := i$ to n do $des(b,t21+(j-1)*q\ ht) := zj$;
$t2 := t21$ end.

Pr12: Case: *'/z eu'* or *'/ eu'* occurs in ***epb*** and *Pd* uses ***k*z eu*** (units) of *OSA*.

if $bef(b,ta) \geq y1$ then begin for $i := 2$ to n do $bef(b,ta+(i-1)*q\ ht) := max(yi,bef(b,ta));\ t1 := ta$ end
else begin $t1 := ta;\ u := 1$;
while $y1 > bef(b,t1) \wedge u \leq k$ do begin $dby := bef(b,t1) - y1$;
for $i := 2$ to n do $bef(b,t1+(i-1)*q\ ht) := yi + dby;\ t1 := t1 + (n-1)*q\ ht;\ u := u+1$ end;
if $u > k$ then $t1 := t1 - (n-1)*q\ ht$ else begin $t11 := t1;\ i := 2$;
while $yi < bef(b,t1) \wedge i \leq n$ do begin $i := i+1;\ t11 := t11 - 1$ end;

if $i \leq n$ then for $j := i$ to n do $bef(b,t11+(j-1)*q\ ht) := yj$,

$t1 := t11$ end end.

if $des(b,ta) \leq z1$ then begin for $i := 2$ to n do $des(b,ta+(i-1)*q\ ht) := min(zi,des(b,ta))$; $t2 := ta$ end

else begin $t2 := ta$; $u := 1$;

while $z1 < des(b,ta) \wedge u \leq k$ do begin $dbz := des(b,t2) - z1$;

for $i := 2$ to n do $des(b,t2+(i-1)*q\ ht) := zi + dbz$; $t2 := t2 +(n-1)*q\ ht$; $u := u+1$ end;

if $u > k$ then $t2 := t2 - (n-1)*q\ ht$ else begin $t21 := t2$; $i := 2$;

while $zi > des(b,t2) \wedge i \leq n$ do begin $i := i+1$; $t21 := t21 - 1$ end;

if $i \leq n$ then for $j := i$ to n do $des(b,t21+(j-1)*q\ ht) := zj$;

$t2 := t21$ end end

Example 2.1. Agent system, *Ap*, has in his model, *M(Lfg)*, of the dish ´*0.3 kg* salmon with fresh potatoes and vegetable` the following property

(´*ds*`,$(epb(P,SN) = (4; (-5,10),(-2,7),(1,4),(4.5,0.5); 7\ min) / 1\ portion$; where *P is a man*))

(*SN* - the need for tasty food). *Ap* concludes from this pattern, if man *P* is hungry ($bef(P,b,ta) = -10$ and $des(P,b,ta) = 14$) then *Ap* expects that the dish *M(Lfg)* will satisfy the hunger of *P* as follows:

\ t =	$ta+7min$	$ta+14min$	$ta+21min$
$bef(P,SN,t)$	-7	-4	-0.5
$des(P,SN,t)$	11	8	4.5

Ap sees that *P* would not have enough. If *Ap* knows that *P* is only little hungry (e.g. ($bef(P,b,ta) = -1$ and $des(P,b,ta) = 5$) then *Ap* expects that the dish *M(Lfg)* will satisfy the hunger of *P* as follows.

\ t =	$ta+7min$	$ta+14min$	$ta+21min$
$bef(P,SN,t)$	-1	1	4.5
$des(P,SN,t)$	5	4	0.5

Example 2.2. Let *vPm* is a virtual skier in an entertainment software. *vPm* is a good skier and he is fond of skiing. He has the following properties in his behavior model, *VS(Shf)*, of skiing:

$E8 =$ (´*ds*`,$((85,100),\ epb(vPm,BW) = (4;(11,4.5),(12,3),(13,2),(14,1);\ 0.33\ h) / h)$,

$(epb(vPm,AN) = (4;(7,12),(8,11),(9,9),(10,8);\ 0.33\ h) / h)$,

$(epb(vPm,EN) = (4;(7.5,4),(8,3),(9,2),(9.5,1);\ 0.33\ h) / h)$,

(*BW* - the need for bodily activities, *AN* - for recognition, acknowledgment and self-esteem, *EN* - for relaxation). Let $bef(vPm,BW,ta) = 0$ and $des(vPm,BW,ta) = 15$. Before skiing, *vPm* expects, with probability *0.85*, that his

BW - desire will be satisfied, during *3 h* of skiing, as follows:

\ t =	ta+0.33 h	ta+0.66h	ta+1h	ta+1.33h	ta+1.66h	ta+2h	ta+2.33h	ta+2.66h	ta+3h
bef(vPm,BW,t)	1	2	3	4	5	6	7	8	9
des(vPm,BW,t)	13.5	12.5	11.5	10	9	8	6.5	5.5	4.5

If *vPm* has values *bef(vPm,AN,ta) = 0, des(vPm,AN,ta) = 18, bef(vPm,EN,ta) = 0, des(vPm,EN,ta) = 14* before the skiing, then he expects the following satisfactions (during *3 h* of skiing):

\ t =	ta+0.33h	ta+0.66h	ta+1h	ta+1.33h	ta+1.66h	ta+2h	ta+2.33h	ta+2.66h	ta+3h
bef(vPm,AN,t)	1	2	3	4	5	6	7	8	9
des(vPm,AN,t)	17	15	14	13	11	10	10	9	8
bef(vPm,EN,t)	0.5	1.5	2	2.5	3.5	4.0	4.5	5.5	6
des(vPm,EN,t)	13	12	11	10	9	8	7	6	5.

fs = upb *upb(Pd,b) = (p; n; (y1,z1),...,(yn,zn); q ht)* [°| /[°| z]*eu*]; *OSA1.Ej*

The meaning: *OSA* supports, in degree *p* ($0 < p \leq 1$), the increasing of *bef(Pd,b,.)* given by the pattern

epb(Pd,b) = (n; (y1,z1),...,(yn,zn); q ht) [°| /[°| z]*eu*]

which occurs in *OSA1.Ej* (i.e. in the property *Ej* occurring in *OSA1*)

Example 2.3. We use the example 2.2. The ski (model *M(mSk)*) of *vPm* and ´good weather for skiing` (model *M(gSw)*) support the skiing of *vPm*. In the model *M(mSk)* are the properties·

('ds`,((85,100), upb(vPm,BW) = (0.25; 4;(11,4.5),(12,3),(13,2),(14,1); 0.33 h) / h; VS(Shf).E8),

(upb(vPm,AN) = (0.15;4 ;(7,12),(8,11),(9,9),(10,8); 0.33 h) / h; VS(Shf).E8),

(upb(vPm,EN) = (0.06;4 ;(7.5,4),(8,3),(9,2),(9.5,1); 0.33 h) / h; VS(Shf).E8)).

In the model *M(gSw)* occur the properties·

('ds`,((85,100), upb(vPm,BW) = (0.25;4 ;(11,4.5),(12,3),(13,2),(14,1); 0.33 h) / h; VS(Shf).E8),

(upb(vPm,AN) = (0.2;4 ;(7,12),(8,11),(9,9),(10,8); 0.33 h) / h; VS(Shf).E8),

(upb(vPm,EN) = (0.4;4 ;(7.5,4),(8,3),(9,2),(9.5,1); 0.33 h) / h; VS(Shf).E8)).

fs = enb *enb(Pd,b) = (n;(y1,z1),...,(yn,zn);q ht)* [°|/[°| z]*eu*]

where *1+yn < y1* and *zn > 1+z1*. The meaning: Case: *OSA* is an object or a situation. According to *Pd* (at time *ta*), there is an activity *AV* in the surrounding of *OSA* such that *AV* uses *OSA* and *Pd* expects that *OSA* (*z eu* of *OSA*, respectively) decreases *bef(Pd,b,ta)* and increases *des(Pd,b,ta)* (when *AV* uses *OSA*) as given in (2). Case: *OSA* is an activity. *Pd* expects that when the activity *OSA* is applied to *Pd* then *bef(Pd,b,ta)* will decrease and *des(Pd,b,ta)* increase as follows:

$$bef(Pd,b,ta+(i-1)*q\ ht) = yi + dby, \text{ if } y1 < bef(Pd,b,ta)$$
$$= yi, \text{ if } yi \le bef(Pd,b,ta) \le y1$$
$$(2) \qquad = bef(Pd,b,ta), \text{ if } y1 \ge bef(Pd,b,ta) < yi$$
$$des(Pd,b,ta+(i-1)*q\ ht) = zi + dbz, \text{ if } des(Pd,b,ta) < z1$$
$$= zi, \text{ if } z1 \le des(Pd,b,ta) \le zi$$
$$= des(Pd,b,ta), \text{ if } z1 \le des(Pd,b,ta) \ge zi, \quad \text{for } i = 1,\ldots,n,$$

where $dby = bef(Pd,b,ta) - y1$ (> 0), $dbz = des(Pd,b,ta) - z1$ (< 0) and $y2-y1 +\ldots+ yn-y1 < 0$. These formulae are applied, by *Pr21* and *Pr22*, similarly as those in (1):

Pr21: Case: neither *'/z eu`* nor *'/ eu`* occurs in *enb*.

if $bef(b,ta) \le y1$ then begin for $i := 2$ to n do $bef(b,ta+(i-1)*q\ ht) := min(yi,bef(b,ta)); t1 := ta$ end

else begin $t1 := ta$;

while $y1 < bef(b,ta)$ do begin $dby := bef(b,t1) - y1$;

for $i := 2$ to n do $bef(b,t1+(i-1)*q\ ht) := yi + dby;\ t1 := t1 + (n-1)*q\ ht$ end;

$t11 := t1;\ i := 2$;

while $yi > bef(b,t1) \wedge i \le n$ do begin $i := i+1;\ t11 := t11 - 1$ end;

if $i \le n$ then for $j := i$ to n do $bef(b,t11+(j-1)*q\ ht) := yj;\ \ t1 := t11$ end.

$des(b,ta+(i-1)*q\ ht)$ is defined analogously as $bef(b,ta+(i-1)*q\ ht)$ in *Pr11*.

Pr22: Case: *'/z eu`* or *'/ eu`* occurs in *enb*.

$bef(b,ta+(i-1)*q\ ht)$ is defined analogously as $des(b,ta+(i-1)*q\ ht)$ in *Pr12;*

$des(b,ta+(i-1)*q\ ht)$ is defined analogously as $bef(b,ta+(i-1)*q\ ht)$ in *Pr12*.

Example 2.4. Let *ES* denotes an entertainment software in which a virtual person *vP* and a virtual physician *vA* are shown. *vP* has model *M(Krk)* of a cancer in which occur the following properties:

$E3 =$ ('ds',((80,100), $enb(vP,GE) = (5; (-22,48),(-23,48),(-24,49),(-24,50),(-25,50); 5\ days)$),

((70,100), $enb(vP,LE) = (5; (-27,47),(-28,48),(-29,49),(-29,50),(-30,50); 5\ days)$)),

(*LE* - the need to be alive, *GE* - to be healthy). *vP* has (at time *ta*) the following values:

$bef(vP,GE,ta) = -1,\ des(vP,GE,ta) = 9,\ bef(vP,LE,ta) = 8,\ des(vP,LE,ta) = 7.$

After the virtual physician *vA* told *vP* that he/she has cancer, *vP* expects that the values of *bef* and *des* would alter, with probability *0.8* and *0.7* (respectively), as given below, if *vP* does nothing against this disease:

\ $t =$	ta+5days	ta+10days	ta+15days	ta+20days	ta+25days.....
$bef(vP,GE,t)$	-2	-3	-3	-4	-5 .....

des(vP,GE,t)	*9*	*10*	*11*	*11*	*11*	.....
bef(vP,LE,t)	*7*	*6*	*6*	*5*	*4*	.....
des(vP,LE,t)	*8*	*9*	*10*	*10*	*11*	......

bef(vP,GE,ta+155days) = -24, bef(vP,GE,ta+160days) = -25,...,bef(vP,GE,ta+275days) = -25, des(vP,GE,ta+265days) = 48, des(vP,GE,ta+270days) = 49, des(vP,GE,ta+275days) = 50, bef(vP,LE,ta+245days) = -28, bef(vP,LE,ta+250days) = -29, bef(vP,LE,ta+255days) = -29, bef(vP,LE,ta+260days) = -30, bef(vP,LE,ta+290days) = -30, des(vP,LE,ta+280days) = 49, des(vP,LE,ta+285days) = 49, des(vP,LE,ta+290days) = 50.

fs = unb *unb(Pd,b) = (p; n; (y1,z1),...,(yn,zn);q ht)* [°| /\[°| z]*eu*]; *OSA1.Ej*

The meaning: *OSA* supports, in degree p $(0 < p \le 1)$, the decreasing of *bef(Pd,b,.)* by *OSA1* according to the following pattern which occurs in *OSA1.Ej*, where *'/z eu'* occurs in *unb(Pd,b)* only if it occurs also in *enb(Pd,b)*:

Ej = ... enb(Pd,b) = (n; (y1,z1),...,(yn,zn); q ht) [°| /\[°| z]*eu*]

Example 2.5. *Hg* is a real dangerous dog. It belongs to a real person *Pg*. Real person *P* is a neighbor of *Pg*. Person *P* has a mobile agent system (a robot, an artificial servant), *AD*, which makes some domestic works. *P* and *Pg* quarrel with one another since 10 years. *P* was 3 times bitten by the dog *Hg*. Nevertheless, *Pg* often does not hold in leash his dog. *AD* has in the model *M(Hg)* of the dog *Hg* (and in the model *M(Pg)* of *Pg*) the property

E2 = ... ((60,100), enb(P,GE) = (5; (5,8),(-8,18),(-6,16),(-3,13),(0,9); 24 h))

(((80,100), unb(P,GE) = (0.7; 5; (5,8),(-8,18),(-6,16),(-3,13),(0,9); 24 h); M(Hg).E2), respectively).

AD concludes from these properties that, with probability *0.8*, *Pg* supports in degree *0.7* the aggressive behavior of the dog *Hg* against *P*.

fs = vnb *vnb(Pd,b) = (p ;n; (y11,z11),...,(y1n,z1n);q ht)* [°\/[°| z]*eu*]; *OSA1.Ej*

The meaning: Instead of the expected decrease of *bef(Pd,b,.)* given by the pattern

enb(Pd,b) = (n; (y1,z1),...,(yn,zn);q ht) [°\/[°| z]*eu*]

which occurs in *OSA1.Ej*, *Pd* expects that *OSA* will alter *bef(Pd,b,.)* and *des(Pd,b,.)*, in degree p, (positive in comparison to *enb(Pd,b) = (...)* in *OSA1.Ej*) as follows:

*bef(Pd,b,t1+(i-1)*q ht) = y1i,* *des(Pd,b,t2+(i-1)*q ht) = z1i,* for *i = 1,...,n*

where $y1i \ge yi$, $z1i < zi$, $0 < p \le 1$, *t1* and *t2* are determined in *Pr21* or *Pr22* for *enb(Pd,b) = (...)*.

Example 2.6. We use the situation described in Example 2 4 After diagnosis made by a virtual specialist in cancer (*vAKs*, in the Software *ES*), the person *vP* built a model *M(vAKs)* of the doctor *vAKs*, which contains the following properties:

$(vnb(vP,GE) = (0.3;\ 5;\ (-12,33),(-11,32),(-11,32),(-10,32),(-9,32);\ 5\ days);\ M(Krk).E3;$ where

$bef(vP,GE,ta) > -18 \wedge$ *I will perform the behaviors prescribed by the doctor vAKs),*

$(vnb(vP,LE) = (0.4;\ 5;\ (-11,35),(-11,35),(-10,35),(-10,34),(-10,33);\ 5\ days);\ M(Krk).E3;$ where

$bef(vP,GE,ta) > -18 \wedge$ *I will perform the behaviors prescribed by the doctor vAKs).*

$fs = vpb$ $\qquad$ $vpb(Pd,b) = (p;\ n;\ (y1l,z1l),\ldots,(yln,zln);q\ ht)$ [°\/[°| *z*]*eu*]; *OSA1.Ej*

The meaning: Instead of the expected increase of *bef(Pd,b,.)* given by the pattern

$epb(Pd,b) = (n;\ (y1,z1),\ldots,(yn,zn);\ q\ ht)$ [°\/[°| *z*]*eu*]

which occurs in *OSA1.Ej*, *Pd* expects that *OSA* will prevent the increasing of *bef(Pd,b,.)*, in degree *p*, and determine *bef(Pd,b,.)* and *des(Pd,b,.)* as follows:

$bef(Pd,b,t1+(i-1)*q\ ht) = yli,\qquad des(Pd,b,t2+(i-1)*q\ ht) = zli,$ for $i = 1,\ldots,n$

where $yli \le yi,\ zli \ge zi,\ 0 < p \le 1,\ t1$ and $t2$ are determined in *Pr11* or *Pr12* for $epb(Pd,b) = (\ldots)$.

Example 2.7. Let *ES1* denotes an entertainment software in which a virtual 14 years old boy, *vJ1*, and a virtual, violent boy *vJg* are shown. The boy *vJ1* takes meal for lunch to the school. His model *M(Frb)* of this meal contains:

$E1 = ('ds',(epb(vJ1,SN) = (5;\ (-1,7),(0,6),(1,5),(2,4),(3,3);\ 3\ min);$ where $bef(vJ1,SN,ta) > -2),\ldots).$

Unfortunately, probably *vJ1* would not lunch because the violent boy *vJg* will take away his meal, with probability *0.9*. *vJ1* has model *M(vJg)* of *vJg*, which include the properties:

$((45,50),\ vpb(vJ1,SN) = (1;\ 5;(-1,7),(-1,7),(-1,7.5),(-1.5,8),(-2,9);3min);\ M(Frb).E1;$where $0.5 > bef(vJ1,SN,ta) > -2),$

$(enb(vJ1,MA) = (4;\ (-3,10),(-5,12),(-8,14),(-8,17);\ 0{,}5\ h);$ where $3 > bef(vJ1,MA,ta) > -4),$

$(enb(vJ1,AN) = (4;\ (-1,9),(-3,11),(-4,12),(-5,13);\ 20\ min);$ where $1 > bef(vJ1,AN,ta) > -3),$

$(enb(vJ1,KS) = (4;\ (-1,6),(-3,8),(-5,9),(-5,12);\ 1\ h);$ where $bef(vJ1,KS,ta) > -3).$

(where *MA* - to have power over people or animals, *KS* - to have no pain).

$fs = epbu$ $\qquad$ $epbu(Pd,b) = (n;\ (x1,d1),\ldots,(xn,dn);\ q\ ht)$

where $25 > xi > 0$ and $40 > di > -40$. The meaning: Case: *OSA* is an object or a situation. *Pd* can execute (at time *ta*) an activity, *AV*, such that when *Pd* uses *OSA* in *AV* then he/she expects that *OSA* will alter the function values *bef(Pd,b,t)* and *des(Pd,b,t)* as given in (3). Case: *OSA* is an activity. When *Pd* executes *OSA* correctly then *Pd* expects the following function values:

(3) $\quad bef(Pd,b,ta+i*q\ ht) = bef(Pd,b,ta) + xi,\quad des(Pd,b,ta+i*q\ ht) = des(Pd,b,ta) + di,$ for $i = 1,\ldots,n.$

Example 2.8. Let *ESF* denotes an entertainment software in which a virtual woman *vF* is shown. Mrs. *vF* thinks, when she wears her golden brooch with rubies, *vgBr*, at a party (behavior *VBtr*) then she increases *bef(vF,bat,.)* according to the following pattern in the model *M(vgBr)*

$E11 = \quad (epbu(vF,bat) = (4;\ (1.5,-1),(2.5,-2),(2.5,-3),(2,-3);\ 1\ h)$

where *bat* denotes the need for attractive appearance.

$fs = upbu \qquad upbu(Pd,b) = (p;\ n;\ (x1,d1),...,(xn,dn);q\ ht);\ OSA1.Ej$

where $25 > xi > 0$ and $40 > di > -40$. The meaning: *OSA* supports, in degree $p\ (0 < p \leq 1)$, the increase of $bef(Pd,b,.)$ by *OSA1* which contains the pattern:

$Ej = ('ds`...epbu(Pd,b) = (n;\ (x1,d1),...,(xn,dn);q\ ht)...)$

Example 2.9. *vPm* denotes a virtual man in the software *ESF* (Example 2.8). *vPm* gave Mrs. *vF* a golden brooch with rubies *vgBr*. Mrs. *vF* has the model *M(vgBr)* of *vgBr*, with the property *E11* given in Example 2.8. *vF* has also the model *M(vPm)* of *vPm*, which contains the property:

$$(upbu(vF,bat) = (1;\ 4;\ (1.5,-1),(2.5,-2),(2.5,-3),(2,-3);\ 1\ h);\ M(vgBr).E11).$$

$fs = enbu \qquad enbu(Pd,b) = (n;\ (x1,d1),...,(xn,dn);\ q\ ht)$

where $25 > xi > 0$ and $40 > di > -40$. The meaning: Case: *OSA* is an object or a situation. According to *Pd* (time *ta*), there is an activity *AV*, in the surrounding of *OSA*, which uses *OSA* and *Pd* expects that *OSA* will decrease $bef(Pd,b,ta)$ and increase $des(Pd,b,ta)$, as given in (4), when it is used by *AV*. Case: *OSA* is an activity. *Pd* expects that when activity *OSA* is applied to *Pd* then $bef(Pd,b,ta)$ will decrease and $des(Pd,b,ta)$ increase as follows:

(4) $\quad bef(Pd,b,ta+i*q\ ht) = bef(Pd,b,ta) - xi, \quad des(Pd,b,ta+i*q\ ht) = des(Pd,b,ta) + di,$ for $i = 1,...,n.$

Example 2.10. The virtual person *vP*, in the software *ES* (Example 2.4), has model *M(kGr)* of the disease influenza, which contains the property

$E5 = ('ds`;(enbu(vP,GE) = (4;(2,2),(3,4),(5,6),(6,7);1\ day)...).$

$fs = unbu \qquad unbu(Pd,b) = (p;\ n;\ (x1,d1),...,(xn,dn);\ q\ ht);\ OSA1.Ej$

where $25 > xi > 0$ and $40 > di > -40$. The meaning: *OSA* supports, in degree $p\ (0 < p \leq 1)$, the decrease of $bef(Pd,b,ta)$ by *OSA1* which contains the pattern:

$Ej = ('ds`...enbu(Pd,b) = (n;\ (x1,d1),...,(xn,dn);\ q\ ht)...).$

Example 2.11. The virtual person *vP*, in Example 2.10, has in the situation model, *SM(kRn)*, of the situation 'to get wet in a cold rain` the property:

$unbu(vP,GE) = (0.6;\ 4;\ (2,2),(3,4),(5,6),(6,7);\ 1\ day);\ M(kGr).E5.$

2.3. Intensity of Stimuli

Pd perceives *OSA* also as a stimulus when in *OSA* are *ds* - properties. Below, we define the intensity of stimulus of a *ds* -property and then of *OSA*, at time *ta*. We assume that in *OSA* occur not more than one properties of the form $fs(Pd,b) = ...$, for a need *b*, where *fs* is defined above.

2.3.1. Positive Stimuli

The patterns *epb, upb, vnb, epbu, upbu* in *OSA* represent positive stimuli. Let *cd(q ht)* = the time *q ht* given in hours, e.g. *cd(2 days) = 48*.

a. $[°|\ (Nba,Nb),]\ epb(Pd,b) = (n;\ (y1,z1),...,(yn,zn);\ q\ ht)\ [°|/[°|\ z]eu]$

Pd expects that the intensity of the positive stimulus of this property in *OSA*, at time *ta*, equals

$$epr(Pd,OSA,epb,b,a,ta) = [°|\ (Nba / Nb)*]\ des(Pd,b,ta) * sqrt(cd(q\ ht) * \Sigma_{i=1..n}((bef(Pd,b,t1+(i-1)*q\ ht) - bef(Pd,b,ta))^2 + cr2 * (des(Pd,b,ta) - des(Pd,b,t2+(i-1)*q\ ht))))$$

where *a* denotes '°' (if '/[° | *z*] *eu*' does not occur in *epb*) or '*k * z eu*' (if '/[° | *z*] *eu*' occurs in *epb* and *Pd* uses *k* * z eu* of *OSA*), '*(Nba,Nb)**' is applied only if '*(Nba,Nb)*' occurs before '*epb*', *bef(Pd,b,t1+(i-1)*q ht), t1, t2* and *des(Pd,b,t2+(i-1)*q ht)* are determined in *Pr11* or *Pr12* (Sect. 2.2), and $0 < cr2 < 1$ is a constant (suggest.: $cr2=0.4$).

b. $[°|\ (Nha,Nh),]\ upb(Pd,b) = (p;\ n;\ (y1,z1),...,(yn,zn);\ q\ ht)\ [°|\ /[°|\ z]\ eu];\ OSA1.Ej$

where $[°|\ (Nba,Nb),]\ epb(Pd,b) = (n;(y1,z1),...,(yn,zn);q\ ht)\ [°|\ /[°|\ z]\ eu]$ occurs in *OSA1* in *Ej*.

$$epr(Pd,OSA,upb,b,a,ta) = [°|\ (Nha / Nh)*]\ cb1 * p * epr(Pd,OSA1,epb,b,a,ta)$$

where $0.1 < cb1 < 1$ is a constant (sugg.: $cb1 = 0.6$).

c. $[°|\ (Nha,Nh),]\ vnb(Pd,b) = (p;\ n;\ (y11,z11),...,(y1n,z1n);\ q\ ht)\ [°|\ /[°|\ z]\ eu];\ OSA1.Ej$

where $[°|\ (Nba,Nb),]\ enb(Pd,b) = (n;\ (y1,z1),...,(yn,zn);\ q\ ht)\ [°|\ /[°|\ z]\ eu]$ occurs in *OSA1* in *Ej*.

$$epr(Pd,OSA,vnb,b,a,ta) = [°|\ (Nha / Nh)*]\ p * [°|\ (Nba / Nb)*]\ des(Pd,b,ta) * sqrt(cd(q\ ht) * \Sigma_{i=1..n}((y1i - yi)^2 + cr2 * (zi - z1i))).$$

d. $[°|\ (Nba,Nb),]\ epbu(Pd,b) = (n;\ (x1,d1),...,(xn,dn);\ q\ ht)$

$$epr(Pd,OSA,b,epbu,°,ta) = [°|\ (Nba / Nb)*]\ des(Pd,b,ta) * sqrt(cd(q\ ht) * \Sigma_{i=1..n}((xi)^2 + cr2 * di)).$$

e. $[°|\ (Nha,Nh),]\ upbu(Pd,b) = (p;\ n;\ (x1,d1),...,(xn,dn);\ q\ ht);\ OSA1.Ej$

where *OSA1.Ej* contains the property *epbu(Pd,b)*, given in (d).

$$epr(Pd,OSA,upbu,b,°,ta) = [°|\ (Nha / Nh)*]\ cb1 * p * epr(Pd,OSA1,epbu,b,°,ta).$$

For *(...fs(Pd,b) = ...; where C)* holds, *epr(Pd,OSA,b,fs,a,ta)* is defined if and only if *C* is true.

2.3.2. Negative Stimuli

a. $[°|\ (Nba,Nb),]\ enb(Pd,b) = (n;\ (y1,z1),...,(yn,zn);\ q\ ht)\ [°|\ /[°|\ z]\ eu]$

Pd expects the following intensity of the negative stimulus of this property in *OSA* at time *ta*:

$$enr(Pd,OSA,enb,b,a,ta) = [°|\ (Nba / Nb)*]\ max(des(Pd,b,t2+(i-1)*q\ ht),\ \text{for } i=1,...,n) * sqrt(cd(q\ ht) * \Sigma_{i=1..n}((bef(Pd,b,t1+(i-1)*q\ ht) - bef(Pd,b,ta))^2 + cr2 * (des(Pd,b,t2+(i-1)*q\ ht) - des(Pd,b,ta))))$$

where '*(Nba,Nb)**' is applied only if '*(Nba,Nb)*' occurs before '*enb*', *bef(Pd,b,t1+(i-1)*q ht), t1, t2* and

*des(Pd,b,t2+(i-1)*q ht)* are determined in *Pr21* or *Pr22* (Sect. 2.2) and *cr2* is the same constant as in Section 2.3.1.

b. [°| *(Nha,Nh),*] *unb(Pd,b) = (p; n; (y1,z1),...,(yn,zn); q ht)* [°| /[°| z]*eu*]; *OSA1.Ej*

where [°| *(Nba,Nb),*] *enb(Pd,b) = (n; (y1,z1),....,(yn,zn); q ht)* [°| /[°| z]*eu*] occurs in *OSA1* in *Ej*.

enr(Pd,OSA,unb,b,a,ta) = [°| *(Nha / Nh)**] *cb1* p* enr(Pd,OSA1,enb,b,a,ta).*

c. [°| *(Nha,Nh),*] *vpb(Pd,b) = (p; n; (y11,z11),...,(y1n,z1n); q ht)* [°| /[°| z]*eu*]; *OSA1.Ej*

where [°| *(Nba,Nb),*] *epb(Pd,b) = (n; (y1,z1),....,(yn,zn); q ht)* [°| /[°| z]*eu*] occurs in *OSA1* in *Ej*.

$$enr(Pd,OSA,vpb,b,a,ta) = [°|\ (Nha / Nh)*]\ p*\ [°|\ (Nba / Nb)*]\ des(Pd,b,ta)\ *$$
$$sqrt(cd(q\ ht)\ *\ \Sigma_{i=1\ \ n}((y1i - yi)^2 + cr2*(z1i - zi))).$$

d. [°| *(Nha,Nh),*] *vnb(Pd,b) = (p; n; (y11,z11),...,(y1n,z1n); q ht)* [°| /[°| z]*eu*]; *OSA1.Ej*

where in *OSA1.Ej* is the pattern *enb(Pd,b)* given in (a).

$$enr(Pd,OSA,vnb,b,a,ta) = [°|\ (Nha / Nh)*]\ p*\ [°|\ (Nba / Nb)*]\ max(z1i,\ \text{for } i=1,...,n)\ *$$
$$sqrt(cd(q\ ht)\ *\Sigma_{i=1\ \ n}((dbyi)^2 + cr2*\ dzi)).$$

where *dbyi = bef(Pd,b,ta) - y1i* if *bef(Pd,b,ta) > y1i, dbyi = 0* otherwise, *dzi = z1i - des(Pd,b,ta)* if *z1i > des(Pd,b,ta), dzi = 0* otherwise.

e. [°| *(Nba,Nb),*] *enbu(Pd,b) = (n; (x1,d1),...,(xn,dn); q ht)*

$$enr(Pd,OSA,b,enbu,°,ta) = [°|\ (Nba / Nb)*]\ (des(Pd,b,ta) + max(di,\text{for } i=1,...,n))*$$
$$sqrt(cd(q\ ht)\ *\ \Sigma_{i=1\ \ n}((xi)^2 + cr2*\ di))$$

f. [°| *(Nha,Nh),*] *unbu(Pd,b) = (p; n; (x1,d1),...,(xn,dn); q ht); OSA1.Ej*

where *OSA1.Ej* contains the pattern *enbu(Pd,b)* given in (e).

enr(Pd,OSA,unbu,b,°,ta) = [°| *(Nha / Nh)**] *cb1 * p* enr(Pd,OSA1,enbu,b,°,ta).*

2.3.3. Intensity of Stimulus of an Object, a Situation or an Activity

Every object, *O*, is perceived as part of a situation, *S*. The stimulus of the object *O* is the stimulus of this object in the situation *S*. Below, we define the intensity of stimulus of *OSA* when:

- *Pd* perceives *OSA* at time *ta*,

- if *OSA* is an object then *OSA* belongs to a situation *S*,

- if *OSA* is an activity then *Pd* could execute this activity or the activity *OSA* could apply *Pd*.

Let $WB = \{b \in Bd(Pd) \mid des(Pd,b,ta) > 0.33 * mdes(Pd,ta)\}$ and $mdes(Pd,ta) = max(des(Pd,b,ta),\ \text{for } b \in Bd(Pd))$.

<u>The intensity of positive stimulus of *OSA*</u>

$$pros(Pd,OSA,ta) = \Sigma_{b\in Bp}\ epr(Pd,OSA,fsp,b,a,ta)$$

where *fsp* denotes *epb, upb, epbu, upbu* or *vnb, epr(Pd,OSA,fsp,b,a,ta)* is defined in Sect. 2.3.1 and

$$Bp = \{b \in WB \mid (...fsp(Pd,b) = ...) \text{ is in } OSA\ \}.$$

<u>The intensity of negative stimulus of *OSA*</u>

$$nros(Pd,OSA,ta) = \Sigma_{b \in Bn}\, enr(Pd,OSA,fsn,b,a,ta)$$

where *fsn* denotes *enb, unb, enbu, unbu, vpb* or *vnb*, *enr(Pd,OSA,fsn,b,a,ta)* is defined in Sect. 2.3.2 and

$$Bn = \{b \in WB \mid (...fsn(Pd,b) = ...) \text{ is in } OSA\ \}.$$

<u>The intensity of stimulus of *OSA* at time *ta*</u>

$$rosa(Pd,OSA,ta) = pros(Pd,OSA,ta) - cr1 * nros(Pd,OSA,ta)$$

where $0.9 < cr1 < 1.4$ is a constant. If we assume that negative stimulus has a stronger effect than a positive one, then *cr1* could be equal to *1.07*.

3. Representation of Joy and Dissatisfaction

We define a function *zful(Pd,b,ta)* which values express contentment, pleasure, joy, great happiness, dissatisfaction, annoyance, anger, grief and suffering of *Pd* with respect to need *b*. In general the values of this functions are interpreted as follows:

$0 \leq zful(Pd,b,ta) < cf1$ - the intensity of contentment of *Pd*, with regard to need *b*, from the intensity *0* (no contentment) to *cf1*;

$cf \leq zful(Pd,b,ta) < cf2$ - the intensity of joy - the greater this value the greater is the joy of *Pd* with regard to *b*, where $cf < cf1 < cf2$;

$cf21 \leq zful(Pd,b,ta)$ - the intensity of happiness - the greater this value the greater is the happiness of *Pd* with regard to *b*, where $cf1 < cf21 < cf2$;

$0 > zful(Pd,b,ta) > cu1$ - the intensity of dissatisfaction of *Pd* with regard to *b* - the smaller this value the greater is the dissatisfaction;

$cu11 > zful(Pd,b,ta) > cu2$ - means annoyance, anger, grief or sadness of *Pd* with regard to *b* - the smaller this value the greater these feelings with regard to need *b*, where $cu11 > cu1$;

$cu21 > zful(Pd,b,ta) > cu3$ - means great physical or mental pain or deep sadness of *Pd* with regard to *b* - the smaller this value the greater these feelings, where $cu11 > cu21 > cu2$;

$cu31 > zful(Pd,b,ta)$ - means extreme suffering of *Pd* with regard to *b*, where $cu21 > cu31 > cu3$.

Value *zful(Pd,b,ta)* alters in following cases:

a1. *Pd* perceives *bef(Pd,b,ta)* and *des(Pd,b,ta)* by its senses or sensors;

a2. *Pd* perceives *OSA*, where *Pd* has a model of *OSA* (e.g. a situation model, a behavior scheme);

a3. *Pd* perceives that he/she is achieving or he/she does not achieve his/her goal situation, *Sz*.

3.1. Alteration of $zful(Pd,b,.)$ in Cases (a1) and (a2)

Case a1: For need b, Pd perceives $bef(Pd,b,ta)$ and $des(Pd,b,ta)$ by its senses or sensors, e.g. as a pain, hunger, sexual desire. Let $dt(b)$ be the time interval after which Pd perceives these values. Examples: $dt(KS) = 10$ *sec.* if Pd has pain, $dt(MA) = 1$ *min* (MA - to have power over people or animals). Let

$WB = \{b \in Bd(Pd) \mid des(Pd,b,ta) > 0.33 * mdes(Pd,ta)\}$ and $mdes(Pd,ta) = max(des(Pd,b,ta)$, for $b \in Bd(Pd))$.

The following operation is done if $b \in WB$:

(3.1) $zful(Pd,b,ta) = zful(Pd,b,ta-dt(b)) + bef(Pd,b,ta) - bef(Pd,b,ta-dt(b)) + cr2*(des(Pd,b,ta-dt(b)) - des(Pd,b,ta))$

where $cr2$ is the same constant as in Sect. 2.3. The initial value of $zful(Pd,b,.)$ can be (in normal cases) equal to the value $bef(Pd,b,ts) > 0$ such that $des(Pd,b,ts) < 0.5$.

Case a2: Pd is, with respect to OSA, in the situation described at the beginning of Sect. 2.3.3. Pd has just identified (at time ta) OSA and has observed that:

- Pd is in the just perceived situation, S, and OSA belongs to S, if OSA is an object;
- Pd is in the situation OSA, if OSA is a situation;
- Pd can execute the activity OSA or the activity can apply Pd, if OSA is an activity.

For each ds - property

$([°| (Na,N),]\ fs(Pd,b) = \ldots\ [°|;$ where $C])$

in OSA, such that if 'where C' occurs then C holds, are executed the following operations:

(3.2) $zful(Pd,b,ta) := zful(Pd,b,ta) + ce1 * ezfb(fs,b,ta)$

where $ezfb(fs,b,ta)$ is defined below and $0.02 < ce1 < 1$ is (for Pd) a constant, e.g. $ce1 = 0.15$ for Pd who reacts not emotional and $ce1 = 0.6$ if Pd reacts emotional.

If fs denotes epb, upb, $epbu$, $upbu$, vnb, vpb and $des(Pd,b,ta) < 0.33 * mdes(Pd,ta)$ or fs denotes enb, unb and $max(des(Pd,b,t2+(i-1)*q\ ht)$, for $i=1,\ldots,n) < 0.33*mdes(Pd,ta)$ (where $des(Pd,b,t2+(i-1)*q\ ht)$ is determined in $Pr21$ or $Pr22$, Sect. 2.2) or fs denotes $enbu$, $unbu$ and $des(Pd,b,ta)+max(di$, for $i=1,\ldots,n) < 0.33 * mdes(Pd,ta)$, then $ezfb(fs,b,ta) = 0$.

Let $des(Pd,b,ta) > 0.33 * mdes(Pd,ta)$. We define $ezfb$ for epb, upb, vnb, $epbu$, $upbu$, vpb:

$ezfb(epb,b,ta) = [°| (Na / N)*]\ (duy(epb,b) + cr2 * (des(Pd,b,ta) - des(Pd,b,t2+(n-1)*q\ ht)))$

where $duy(epb,b) = max(bef(Pd,b,t1+(i-1)*q\ ht)$, for $i=1,\ldots,n) - bef(Pd,b,ta)$, and $bef(Pd,b,t1+(i-1)*q\ ht)$, $des(Pd,b,t2+(n-1)*q\ ht)))$ are determined in $Pr11$ or $Pr12$ (Sect. 2.2).

$ezfb(upb,b,ta) = [°| (Na / N)*]\ cb1 * p * ezfb(epb,b,ta)$

where $([°| (Nba,Nb),]\ epb(Pd,b) = \ldots)$ occurs in $OSA1.Ej$.

$$ezfb(vnb,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ p\ *[^{\circ}|\ (Nba\,/\,Nb)*]\ (duy1(vnb,b) + cr2*\ (zn - z1n - dzn)$$

where $([^{\circ}|\ (Na,N),]\ vnb(Pd,b) = (p;\ n;\ (y11,z11),\ldots,(y1n,z1n);\ q\ ht);\ OSA1.Ej)$ occurs in OSA, $duy1(vnb,b) = y1n - yn - dbyn$, $([^{\circ}|\ (Nba,Nb),]\ enb(Pd,b) = (n;\ (y1,z1),\ldots,(yn,zn);\ q\ ht))$ is in $OSA1.Ej$, $dbyn = bef(Pd,b,ta) - y1n$ if $bef(Pd,b,ta) > y1n$, $dbyn = 0$ otherwise, $dzn = z1n - des(Pd,b,ta)$ if $z1n > des(Pd,b,ta)$, $dzn = 0$ otherwise.

$$ezfb(epbu,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ (duy(epbu,b) - cr2\ *\ dn)$$

where $duy(epbu,b) = max(xi,$ for $i=1,\ldots,n)$.

$$ezfb(upbu,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ cb1\ *\ p*\ ezfb(epbu,b,ta)$$

where $(\ldots epbu(Pd,b) = \ldots)$ is in $OSA1.Ej$.

Let $([^{\circ}|\ (Na,N),]\ vpb(Pd,b) = (p;\ n;\ (y11,z11),\ldots,(y1n,z1n);\ q\ ht);\ OSA1.Ej)$ occurs in OSA, $([^{\circ}|\ (Nba,Nb),]\ epb(Pd,b) = (n;\ (y1,z1),\ldots,(yn,zn);\ q\ ht))$ is in $OSA1.Ej$ and $duy1(vpb,b) = y1n - yn$.

$$ezfb(vpb,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ p*\ [^{\circ}|\ (Nba\,/\,Nb)*]\ (duy1(vpb,b) + cr2*\ (zn - z1n)).$$

Now we define $ezfb$ for enb and unb. We assume, $max(des(Pd,b,t2+(i-1)*q\ ht),$ for $i=1,\ldots,n) > 0.33*mdes(Pd,ta)$.

$$ezfb(enb,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ (duy(enb,b) + cr2*\ (des(Pd,b,ta) - des(Pd,b,t2+(n-1)*q\ ht))),$$

where $duy(enb,b) = min(bef(Pd,b,t1+(i-1)*q\ ht),$ for $i=1,\ldots,n) - bef(Pd,b,ta)$, and $bef(Pd,b,t1+(i-1)*q\ ht)$, $des(Pd,b,t2+(n-1)*q\ ht)))$ are determined in $Pr21$ or $Pr22$ (Sect. 2.2).

$$ezfb(unb,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ cb1\ *\ p*\ ezfb(enb,b,ta)$$

where $([^{\circ}|\ (Nba,Nb),]\ enb(Pd,b) = \ldots)$ is in $OSA1.Ej$.

Let $des(Pd,b,ta) + max(di,$ for $i=1,\ldots,n) > 0.33*\ mdes(Pd,ta)$ and $duy(enbu,b) = -\ max(xi,$ for $i=1,\ldots,n)$. We define $ezfb$ for $enbu$ and $unbu$:

$$ezfb(enbu,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ (duy(enbu,b) - cr2\ *\ dn)$$

$$ezfb(unbu,b,ta) = [^{\circ}|\ (Na\,/\,N)*]\ cb1\ *p*\ ezfb(enbu,b,ta)$$

where $(\ldots enbu(Pd,b) = \ldots)$ is in $OSA1.Ej$.

After operations (3.2) are executed, for ds properties in OSA, Pd can perceive the alterations of $bef(Pd,b,t)$ and $des(Pd,b,t)$ by senses or sensors (or simulate them). In this case, the operations (3.1) are executed.

3.2. Satisfaction and Dissatisfaction when *Pd* is Achieving a Goal

A goal is a situation, Sz, having relative great value $rosa(Pd,Sz,ta)$, at time ta, and which can be achieved, according to Pd. First we consider the case (a3), where Pd realizes achieving of a goal situation Sz: Pd decided (at time $t1$), on the basis of his/her motivation function and his/her activity descriptions, that Sz is the situation which Pd will achieve till time $t2$. Let $pz(t)$ be the probability of achieving the goal Sz (as Pd estimates at time t). $pz(t)$ can be interpreted as the hope of Pd (at time t) of achieving the goal Sz. Situation Sz is added to list LZS as follows:

(3.3) *(Sz,pz(t),t1,t2; dsE1,...,dsEu; AV1,...,AVw;...)*

where *dsEi* denotes a new *ds* - property of the goal *Sz* (added to the list in the time *(t1,ta)*), and *AVe* ($e \leq w$) are the activities by which *Pd* plans to achieve the situation *Sz*. *dsEi* has one of the following two forms:

('dser'; ([°| (Na,N),] fs(Pd,b) = ...) - *Pd* expects (with probability *Na / N*) that, (immediately) after he/she achieves the situation *Sz*, *bef(Pd,b,.)* and *des(Pd,b,.)* will change according to the pattern *fs(Pd,b)* = ..., where *fs* denotes the same symbols as in Sect. 3.1 (in most cases, *fs* is here a pattern that increases *bef(Pd,b,.)*);

('dsne'; ([°| (Na,N),] fs(Pd,b) = ...) - *Pd* expects (with probability *Na / N*) that, when he/she does not achieve the goal situation *Sz*, *bef(Pd,b,.)* and *des(Pd,b,.)* will change according to the pattern *fs(Pd,b)* = ... (in most cases, *fs* is here a pattern that decreases *bef(Pd,b,.)*)

Example 3.1. *vH* is a virtual man in an entertainment software. He has a small business. His goal situation, *Sei*, is to increase the income of his business at least by *2.5 %* in one year. He hopes to achieve this goal with probability $pz(t1) = 0.85$. After *2* month he concludes that, if he does not achieve this goal and the income increases only by *x %* (or decreases if $x < 0$) then his reputation as a manager would decrease as given by the pattern:

$$('dsne'; (91,100), enb(vH,AN) = (5; (2.2*(2-x),2.5*(2-x)), (2.1*(2-x),2.4*(2-x)), (2*(2-x),2.4*(2-x)), (1.9*(2-x),2.3*(2-x)), (1.9*(2-x),2.3*(2-x)); 3\ days), \text{ where } -6 < x \leq 2))$$

(*AN* - the need for recognition, acknowledgment and self-esteem). However, if *vH* achieves the goal - the income of his business would increases by *(2.5+z)%* ($z>0$) - then his manager reputation would increase as given by the pattern

$$('dsre'; (98,100), epb(vH,AN) = (5;(2.8*(1+z),-1.8*(1+z)), (2.6*(1+z),-1.6*(1+z)), (2.6*(1+z),-1.6*(1+z)), (2.5*(1+z),-1.5*(1+z)), (2.4*(1+z),-1.4*(1+z)); 3\ days), \text{ where } 0 \leq z \leq 5)).$$

These two properties are attached to the goal situation *Sei* (in *LZS*) at time *t1+2 month*.

Goal situation *Sz* in *LZS* determines the need, *bsz*, of *Pd* to achieve the situation *Sz*.. The reason for the need *bsz* (a motivation) is the expected increase of satisfaction, *efrz(Pd,Sz,ta)*, when the goal *Sz* would be achieved. This expected (at time *ta*) increase of satisfaction can be expressed as follows

$$efrz(Pd,Sz,ta) = \Sigma_{b \in Bz}\ ezfb(sf,b,ta) * pz(ta)$$

where $Bz = \{b \mid (...fs(Pd,b) = ...)$ occurs in *Sz* or *('dser'; (...fs(Pd,b) = ...))* is attached to *Sz* in the list *LZS* $\}$ and *ezfb(sf,b,.)* is defined in Sect. 3 1. When *Pd* is achieving the goal *Sz*, *zful(Pd,b,.)* alters as given in (3.2), where *OSA* denotes the situation *Sz* with the *'dser'* - properties given in (3.3). Thus, when *Pd* perceives (at time *t2a*) that he/she will achieve the goal *Sz*, the satisfaction and joy increases by

$$frez(Pd,Sz,t2a) = ce1 * efrz(Pd,Sz,t2a) \quad \text{where } 0.9 < pz(t2a) \leq 1.$$

When *Pd* has achieved the situation *Sz*, *Pd* perceives *bef(Pd,b,.)* and *des(Pd,b,.)* by senses or sensors, for $b \in Bz$.

These changes of $bef(Pd,b,.)$ and $des(Pd,b,.)$ increase $zful(Pd,b,.)$ as given in (3.1), for $b \in Bz$, and they must not agree with the patterns $(...fs(Pd,b) =...)$ in Sz and $('dser';\ (...fs(Pd,b) = ...))$ attached to Sz in LZS. The satisfaction and joy resulting from achieving the goal Sz, at time $t > t2a$, equals

$$frz(Pd,Sz,t2a,t) = \Sigma_{b\in Bz}\ zful(Pd,b,t) - zful(Pd,b,t2a\text{-}dt1)$$

when Pd perceives the said changes of $bef(Pd,b,.)$ and $des(Pd,b,.)$ (in time $(t2a\text{-}dt1,t)$) as the result of achieving the goal Sz, where $0 < dt1 < 15\ min$.

<u>Satisfaction and dissatisfaction when achieving of goal situation is realized</u>. In order to achieve goal Sz, Pd performs some activities $AV1,...,AVw$ (s. (3.3)). To each activity AVe, we attach (in (3.3)) the following property:

$$('dsz';\ ([^{\circ}|\ (Nea,Ne),]\ re(bsz) = he)),\ \text{ where } 0 < he \le 1.$$

The meaning: Pd thinks, that AVe realizes the achieving of the situation Sz in degree he, i.e. if Pd performs AVe correct and achieves the expected intermediate goal situation (intermediate goal), $zSze$, then Pd thinks he/she approached the goal Sz in degree he. Before Pd performs the activity AVe, Pd expects that he/she achieves the intermediate goal $zSze$, with probability Nea / Ne, and then (after $zSze$ has been achieved, at time $ta+xt$) will increase his/her satisfaction and joy, i.e. the value $\Sigma_{b\in Bd(Pd)}\ zful(Pd,b,ta+xt)$, by $he * ce1 * efrz(Pd,Sz,ta)$.

If an obstacle appears which prevents (or makes difficult) either the continuation of the activity AVe or the achieving of the intermediate goal $zSze$, in degree $0 < ge \le 1$, then the dissatisfaction of Pd increases by the value $ge * he * ce1 * efrz(Pd,Sz,ta)$, i.e. by this value decreases $\Sigma_{b\in Bd(Pd)}\ zful(Pd,b,ta+xt)$. If $ge = 1$ then (according to Pd) Pd cannot achieve the intermediate goal $zSze$ by the activity AVe.

<u>Dissatisfaction and disappointment when *Pd* does not achieve a goal</u>. At time $ta\text{-}xt$, Pd believed that he/she would achieve the goal situation Sz with probability $pz(ta\text{-}xt)$, where xt is a small interval of time. In the time $(ta\text{-}xt,ta)$, Pd becomes aware that he/she did not or cannot achieve Sz. The intensity of the dissatisfaction and disappointment, at time ta, equals

$$unen(Pd,Sz,ta) = ce1 * (efrz(Pd,Sz,ta\text{-}xt) - \Sigma_{b\in Bnz}\ ezfb(sf,b,ta))$$

where $Bnz = \{b \mid ('dsne';(...fs(Pd,b) = ...))$ is attached to Sz in the list $LZS\}$ and $ezfb(sf,b,.)$ is defined in Sect. 3.1. Also the following operations are executed:

$$zful(Pd,b,ta) := zful(Pd,b,ta) - ce1 * pz(ta\text{-}xt) * ezfb(fs,b,ta),\ \text{ for } b \in Bz,$$

$$zful(Pd,b,ta) := zful(Pd,b,ta) + ce1 * ezfb(fs,b,ta),\ \text{ for } b \in Bnz.$$

Afterwards (time $t \ge ta$) Pd perceives $bef(Pd,b,t)$ and $des(Pd,b,t)$ by senses or sensors for $b \in Bnz$. These changes of $bef(Pd,b,.)$ and $des(Pd,b,.)$ cause the decrease of values $zful(Pd,b,t)$ as given in (3.1) for $b \in Bnz$.

4. Feelings: Affection, Love, Aversion, Anger

In this section, we describe formally the feelings to/for an object, a situation or an activity (*OSA*). liking, sympathy, affection, love, dislike, aversion, anger, hate. Dislike, anger and hate are considered more exactly in Sect. 6. Human has needs which are associated with affection and love towards objects. Examples: *ELM* -the love of mother to her child, *MU* - the need for music, *NaW* - the need to have knowledge in the area of natural science. The mentioned emotions originate not only from such needs. When a human or a mammal, *Pa,* perceives that an another human or mammal, *Pan,* caused an increase (or a decrease) of *bef(Pa,b,.),* then *Pan* arises sympathy, affection or love of *Pa* towards *Pan* (dislike, aversion, anger or hate of *Pa* towards *Pan,* respectively). These feelings *Pan* arises also if *Pan* is not a living object, e.g. *Pa* likes his car, affection to Alps, affection for alcohol, aversion to dung. Also an activity, *AV,* causes such feelings when *AV* changes *bef(Pa,b,.),* e.g. person *P* is fond of skiing. We describe the mentioned states of feelings of *Pd* to/for *OSA* by functions:

zulieb(Pd,OSA,ta) - the intensity of liking and affection of *Pd* to/for *OSA* (at time *ta*) - the greater this value the stronger is the positive feeling of *Pd* for *OSA;*

abhas(Pd,OSA,ta) - the intensity of dislike, annoyance and anger of *Pd* to/for *OSA* - the greater this value the stronger is the negative feeling of *Pd* for *OSA.*

The values of these functions are determined when *Pd* perceives that:

i. *OSA* caused, supported or prevented an increase or decrease of ***bef(Pd,b,ta-xtb)*** or ***des(Pd,b,ta-xtb)*** in time *(ta-xtb, ta);*

ii. *OSA* carried out, supported or prevented achieving of a goal situation listed in *LZS* in time ***(ta-xtb, ta).***

4.1. *OSA* Effected Alteration of Values *bef(Pd,b,.), des(Pd,b,.)*

First, we consider the case (i). ***abhas(Pd,OSA,ta)*** increases when *Pd* perceives that:

a1. *OSA* caused or supported, in degree ***g(b)*** ($0< g(b)\leq 1$), the decrease of ***bef(Pd,b,ta-xtb)*** by ***dy(b),*** or *OSA* prevented, in degree ***g(b)***, the increase of ***bef(Pd,b,ta-xtb)*** by ***dy(b),*** in the time ***(ta-xtb,ta);*** i.e. ***dy(b)*** = ***bef(Pd,b,ta-xtb)*** - ***bef(Pd,b,ta)*** or if no *OSA1* (e.g *OSA*) had prevented the increase of ***bef(Pd,b,ta-xtb)*** then ***bef(Pd,b,ta)*** would have been (according to *Pd*) greater by ***dy(b)*** ($dy(b) > 0.1$);

a2. if *OSA* is an object, ***Ob,*** then *Pd* thinks that *Ob* had no right to perform or to support the decrease of ***bef(Pd,b,ta-xtb)*** by ***dy(b)*** or to prevent the increase of ***bef(Pd,b,ta-xtb)***;

a3. *Pd* believes (perceives) that *OSA* caused or supported consciously, in degree $0 \leq nr(OSA,b) \leq 1$, the decrease of ***bef(Pd,b,ta-xtb)*** by ***dy(b)*** or prevented consciously, in degree ***nr(OSA,b),*** the increase of ***bef(Pd,b,ta-xtb)*** by ***dy(b).***

Most of educated people have $0 \leq nr(nOPT,b) \leq 0.2$ where *nOPT* denotes a not living object, a plant or a

primitive animal. An inhabitant of a primeval forest, 2000 years ago, had $0.7 \leq nr(thunder\ and\ lightning,\ bs) \leq 1$ for a safety need *bs*. Soldiers of an army, *A1*, who fight against soldiers, *SA2*, of an army *A2*, have $0.8 \leq nr(SA2,bs) \leq 1$.

When (a1), (a2) and (a3) take place then *abhas* and *zulieb* change as follows:

(4.1) $abhas(Pd,OSA,ta) := abhas(Pd,OSA,ta) + nr(OSA,b) * g(b) * dy(b) * des(Pd,b,ta)$

(4.2) $zulieb(Pd,OSA,ta) := zulieb(Pd,OSA,ta) - ca * nr(OSA,b) * g(b) * dy(b) * des(Pd,b,ta)$

where *ca* is a constant for *Pd*, $0 < ca \leq 0.6$ (sugg.: $ca = 0.2$).

Case: (a2) does not hold, i.e. (a1) and (a2) holds, *OSA* is an object, *Ob*, and *Pd* thinks that *Ob* has the right to perform and to support the decrease of $bef(Pd,b,ta\text{-}xtb)$ by $dy(b)$ or to prevent the increase of $bef(Pd,b,ta\text{-}xtb)$. In this case, only operation (4.2) is executed.

$zulieb(Pd,OSA,ta)$ increases when *Pd* perceives that:

b1. *OSA* caused or supported, in degree $p(b)$ $(0 < p(b) \leq 1)$, the increase of $bef(Pd,b,ta\text{-}xtb)$ by $dz(b)$ or prevented, in degree $p(b)$, the decrease of $bef(Pd,b,ta\text{-}xtb)$ by $dz(b)$, in the time $(ta\text{-}xtb,ta)$, i.e. $dz(b) = bef(Pd,b,ta) - bef(Pd,b,ta\text{-}xtb)$ or if no *OSA1* (e.g. *OSA*) had prevented the decrease of $bef(Pd,b,ta\text{-}xtb)$ then $bef(Pd,b,ta)$ would have been (according to *Pd*) smaller by $dz(b)$ $(dz(b) > 0.1)$;

b2. if *OSA* is an object, *Ob*, then *Pd* thinks that *Ob* was not obliged to perform or to support the increase of $bef(Pd,b,ta\text{-}xtb)$ by $dz(b)$ or to prevent the decrease of $bef(Pd,b,ta\text{-}xtb)$;

b3. *Pd* believes (perceives) that *OSA* consciously caused or supported, in degree $0 \leq pr(OSA,b) \leq 1$, the increase of $bef(Pd,b,ta\text{-}xtb)$ by $dz(b)$ or *OSA* prevented, in degree $pr(OSA,b)$, the decrease of $bef(Pd,b,ta\text{-}xtb)$ by $dy(b)$.

Most of educated people have $0 \leq pr(nOPT,b) \leq 0.2$, where *nOTP* denotes the same objects as above. However, a successful soccer-player can have values $0.5 \leq pr(FB,AN) \leq 0.8$, $0.5 \leq pr(FB,Rei) \leq 0.8$, where *FB* - ball for playing soccer, *AN* - the need for recognition, acknowledgment and self-esteem, *Rei* - to be rich. Inhabitant of a primeval forest, 2000 years ago, who looked upon a big oak tree as a deity, had $0.7 \leq pr(oak,be) \leq 1$ for some needs *be*. A not educated farmer can have $pr(good\ field,gE) = 0.5$, $pr(bad\ field,gE) = 0$, where *gE* denotes 'to have good crop'. An agrarian engineer has: $pr(good\ field,gE) = pr(bad\ field,gE) = 0$. An enthusiastic musician can have $0.5 \leq pr(music,MU) < 1$

When (b1), (b2) and (b3) take place then *zulieb* and *abhas* change as follows:

(4.3) $zulieb(Pd,OSA,ta) := zulieb(Pd,OSA,ta) + pr(OSA,b) * p(b) * dz(b) * des(Pd,b,ta\text{-}xtb)$

(4.4) $abhas(Pd,OSA,ta) := abhas(Pd,OSA,ta) - ca * pr(OSA,b) * p(b) * dz(b) * des(Pd,b,ta\text{-}xtb)$.

4.2. Involvement of *OSA* when *Pd* Realizes Achieving a Goal Situation.

We consider the case (ii) (s. Sect. 4, the beginning). First, we assume that *OSA* realizes or supports achieving

of a goal situation *Sz* of *Pd*. $zulieb(Pd,OSA,.)$ increases when *Pd* realizes achieving of an intermediate goal situation, *zSze*, by an activity *AVe*, in time $(ta\text{-}zt,ta)$, and perceives that:

- *OSA* performed or supported, in degree $0< zpe\leq 1$, achieving of the intermediate goal *zSze* in time $(ta\text{-}zt,ta)$;
- if *OSA* is an object (*Ob*) then *Pd* thinks that *Ob* was not obliged to perform or to support the achieving of the intermediate goal *zSze*;
- *Pd* believes (perceives) that *OSA* consciously, in degree $pr(OSA,bsz)$, performed or supported, in degree *zpe*, the achieving of the intermediate goal *zSze*, where *bsz* denotes the need to achieve the goal *Sz*;

The symbols *AVe*, *zSze* have the same meaning as in Sect. 3.2. $pr(OSA,b)$ has the same meaning as in Sect. 4.1. Let

$Bzz = \{(fs,b) \mid [des(Pd,b,ta\text{-}zt) > 0.33 * mdes(Pd,ta\text{-}zt) \wedge fs$ denotes *epb, upb, epbu, upbu, vnb, vpb* $\vee$

$des(Pd,b,ta) > 0.33 * mdes(Pd,ta) \wedge fs$ denotes *enb, unb, enbu, unbu*$] \wedge [(...fs(Pd,b) = ...)$ occurs in *Sz* $\vee$

('dser'; (...fs(Pd,b) = ...)) is attached to *Sz* in the list *LZS*$]\}$.

For $(fs,b)\in Bzz$, *zulieb* and *abhas* are changed as follows:

(4.5) $zulieb(Pd,OSA,ta) := zulieb(Pd,OSA,ta) + zul(OSA,b,ta)$

(4.6) $abhas(Pd,OSA,ta) := abhas(Pd,OSA,ta) - ca * zul(OSA,b,ta)$

where. $zul(OSA,b,ta) = ce2 * [°|(Nba / Nb)*]\ pr(OSA,bsz) * zpe * he * pz(ta\text{-}zt) * duy(fs,b) * desz(b,ta)$,

zpe, he, $pz(t)$ have the same meaning as in Sect. 3.2, $0 < ce2 \leq 1$ (sugg. $ce2 = ce1+0.2$),

$desz(b,ta) = des(Pd,b,ta\text{-}zt)$, if *fs* denotes *epb, upb, epbu, upbu, vnb, vpb*

$= des(Pd,b,ta)$, if *fs* denotes *enb, unb, enbu, unbu,*

$duy(epb,b)$, $duy(epbu,b)$, $duy(enb,b)$, $duy(enbu,b)$, $duy1(vnb,b)$, $duy1(vpb,b)$ are defined in Sect. 3.1,

$duy(upb,b) = cb1 * p * duy(epb,b)$, $duy(upbu,b) = cb1 * p * duy(epbu,b)$, $duy(vnb,b) = p * duy1(vnb,b)$,

$duy(vpb,b) = p * duy1(vpb,b)$, $duy(unb,b) = cb1 * p * duy(enb,b)$, $duy(unbu,b) = cb1 * p * duy(enbu,b)$.

<u>*OSA* prevents achieving a goal situation *Sz*.</u> $abhas(Pd,OSA,ta)$ increases when *Pd* realizes achieving of intermediate goal situation *zSze* of the goal *Sz* by an activity *AVe*, in time $(ta\text{-}zt,ta)$, and perceives that:

- *OSA* prevented, in degree $0 < zge \leq 1$, the achieving of the intermediate goal *zSze* in time $(ta\text{-}zt,ta)$;
- if *OSA* is an object (*Ob*) then *Pd* thinks that *Ob* had no right to prevent the achieving of the intermediate goal *zSze*;
- *Pd* believes (perceives) that *OSA* consciously, in degree $nr(OSA,bsz)$, prevented, in degree *zge*, the achieving of the intermediate goal *zSze*.

For (fs,b) in *Bzz*, *zulieb* and *abhas* are changed as follows:

(4.7) $abhas(Pd,OSA,ta) := abhas(Pd,OSA,ta) + abh(b,ta)$

(4.8) $zulieb(Pd,OSA,ta) := zulieb(Pd,OSA,ta) - ca * abh(b,ta)$

where: $abh(b,ta) = [°|\ (Nba\ /\ Nb)^*]\ nr(OSA,bsz)^*\ zge^*\ he^*\ pz(ta\text{-}zt)^*\ duy(fs,b)^*\ desz(b,ta)$, zge, he, $pz(t)$, $desz(b,ta)$ and $duy(fs,b)$ have the same meaning as above. Additionally, for $b \in Bnz$ (Bnz is defined in Sect. 3.2), are executed the operations:

(4.9) $abhas(Pd,OSA,ta) := abhas(Pd,OSA,ta) - nr(OSA,bsz)\ ^*zge^*\ he^*\ pz(ta\text{-}zt)^*\ duy(fs,b)^*\ des(Pd,b,ta)$

(4.10) $zulieb(Pd,OSA,ta) := zulieb(Pd,OSA,ta) + ca^*\ nr(OSA,bsz)^*\ zge^*\ he^*\ pz(ta\text{-}zt)^*\ duy(fs,b)^*\ des(Pd,b,ta)$.

Remark: $duy(fs,b) < 0$ for almost all b in Bnz.

If OSA is an object, Ob, and Pd thinks Ob had the right to prevent the achieving of the intermediate goal $zSze$ then only $zulieb$ changes as given in (4.8) und (4.10).

5. Retaliation and Revenge

When $abhas(Pd,Ob,ta)$ increases and Ob is a living object then it can arise the need, $bvr(Ob)$, of Pd for retaliation and revenge on Ob, if $nr(Ob,b)>cr$ for some needs $b \in Bd(Pd)$ (sugg.: $cr=0.1$). Usual in this case, Ob denotes a human, people, an organization (if Pd is a human) or a number of animals. If Pd is a mammal (e.g. a bulldog) then Ob may be also a non living object. $bef(Pd,bvr(Ob),.)$ and $des(Pd,bvr(Ob),.)$ depend on the degree of inclination, $0 \leq gr(Pd) \leq 1$, of Pd for revenge. If OSA is an object Ob such that $nr(Ob,b) > cr$, for some b in $Bd(Pd)$, and $abhas(Pd,Ob,ta)$ increases as given in (4.1), (4.7) or (4.9), then also the following operations are executed (changes of $bef(Pd,bvr(Ob),.)$ and $des(Pd,bvr(Ob),.)$):

if $bvr(Ob) \in Bd(Pd)$ then begin $bef(Pd,bvr(Ob),ta) := max(bef(Pd,bvr(Ob),ta) - dbh(b), -20)$;

$des(Pd,bvr(Ob),ta) := min(des(Pd,bvr(Ob),ta) + ch1^*\ dbh(b), 50)$ end

else begin $Bd(Pd) := Bd(Pd) \cup bvr(Ob)$;

$bef(Pd,bvr(Ob),ta) := max(18 - dbh(b), -20)$; $des(Pd,bvr(Ob),ta) := min(ch1^*\ dbh(b), 50)$ end

where $0.8 \leq ch1 \leq 2$ is a constant (sugg. $ch1 = 1.3$),

$dbh(b) = gr(Pd)^*\ nr(Ob,b)^*\ g(b)^*\ sqrt(dy(b)^*\ 0.5^*\ des(Pd,b,ta))$, if (4.1) was executed

$= [°|\ (Nba\ /\ Nb)^*]\ gr(Pd)^*\ nr(Ob,bsz)^*\ zge^*\ he^*\ pz(ta\text{-}zt)^*\ sign(duy(fs,b))^*$

$sqrt(|\ duy(fs,b)\ |^*\ 0.5^*\ desz(b,ta))$, if (4.7) was executed

$= [°|\ (Nba\ /\ Nb)^*]\ gr(Pd)^*\ nr(Ob,bsz)^*\ zge\ ^*\ he\ ^*\ pz(ta\text{-}zt)^*\ sign(duy(fs,b))^*$

$sqrt(|\ duy(fs,b)\ |^*\ 0.5^*\ des(Pd,b,ta))$, if (4.9) was executed,

and the other used symbols have the same meaning as in (4.1), (4.7) und (4.9).

$bef(Pd,bvr(Ob),.)$ increases when $zulieb(Pd,Ob,.)$ increases and $abhas(Pd,Ob,.)$ decreases. If OSA is an object (Ob), $bvr(Ob) \in Bd(Pd)$ and $pr(Ob,b) > cr$ and operations (4.3) or (4.5) were executed, then $bef(Pd,bvrOb),.)$ and $des(Pd,bvr(Ob),.)$ change as follows:

$$bef(Pd,bvr(Ob),ta) := min(bef(Pd,bvr(Ob),ta) + ca2 * bsh(b),\ 12)$$

$$des(Pd,bvr(Ob),ta) := max(des(Pd,bvr(Ob),ta) - ch1 * ca2 * bsh(b),\ 2)$$

where $0 < ca2 < 4$, the used symbols have the same meaning as in (4.3) and (4.5),

$bsh(b) = pr(Ob,b) * p(b) * sqrt(dz(b) * 0.5 * des(Pd,b,ta\text{-}xt))$, if (4.3) was executed

$= [°|\ (Nba / Nb)*]\ pr(Ob,bsz) * zpe * he * pz(ta\text{-}zt) * sign(duy(fs,b)) * sqrt(|\ duy(fs,b)\ | * 0.5 * desz(b,ta))$,

if (4.5) was executed.

$ca2$ is a constant which must be determined for each Pd. For people who are inclined to forgive holds $1.5 < ca2 < 4$. For vindictive people holds $0 < ca2 < 0.8$.

6. Frustration, Anger, Fear

6.1. Frustration, Depression, Sadness, Anger

First, we define apathy. Pd is apathetic in time $(ta\text{-}cta,ta)$ if $-0.2 * cf \leq zful(Pd,b,t) \leq 0.2 * cf$, for $b \in Bd(Pd)$, and $mdes(Pd,t) < 2$, for $ta\text{-}cta \leq t \leq ta$, where $cta \geq 2$ *weeks* and cf is the constant introduced at the beginning of Sect. 3. To $Bd(Pd)$ can belong also needs, bsz, 'to achieve situation Sz'. Let

$$WB = \{b \in Bd(Pd) \mid des(Pd,b,ta) > 0.33 * mdes(Pd,ta)\ \}.$$

Frustration. Pd may be frustrated with respect to need b, at time ta, when:

i. Pd is not joyful at time ta, i.e. $zful(Pd,b1,ta) < cf$ for $b1 \in WB$;

ii. $zful(Pd,b,ta) < 0$ and Pd thinks that he/she can perform only activities $AVb1,\dots,AVbr$ which either decrease $zful(Pd,b,ta)$ by $dzf(b) \geq 0$, with probability $pf(b,ta)$, or increase $zful(Pd,b,ta)$ by $dzh(b) \geq 0$ with probability $ph(b,ta)$.

Pd is frustrated with respect to $b \in WB$, at time ta, with intensity

$$frusb(Pd,b,ta) = -\ zful(Pd,b,ta) + pf(b,ta) * dzf(b) - ph(b,ta) * dzh(b)$$

if (i) and (ii) hold and $frusb(Pd,b,ta) > 0$. Let

$$Bf = \{b \in WB \mid Pd \text{ is frustrated with respect to } b \text{ at time } ta\ \}.$$

The intensity of frustration of Pd at time ta:

$$frust(Pd,ta) = \Sigma_{b \in Bf}\ frusb(Pd,b,ta)\ ).$$

Depression.. We use the above introduced symbols. Pd is depressed with respect to need b, at time ta, when:

- Pd is frustrated with respect to need b, $frusb(Pd,b,ta) > cf1$ and, according to Pd, $frusb(Pd,b,t) > cf1$ for $ta < t \leq ctd$;
- according to Pd, $ph(b,t) = 0$, for $ta < t \leq ctd$, i.e. Pd thinks he/she cannot perform an activity which would increase $zful(Pd,b,ta)$ (or $bef(Pd,b,ta)$) in the time (ta,ctd);
- according to Pd, $zful(Pd,b1,t) < 0.5 * cf$ for $b1 \in Bd(Pd)$ and $ta < t \leq ctd$;

where $ctd - ta > 1$ *year* (sugg.: $ctd - ta = 3$ *years*) and cf, $cf1$ are the constants introduced at the beginning of Sect. 3.

The intensity of depression of *Pd* with respect to *b* at time *ta*:

$$depb(Pd,b,ta) = frusb(Pd,b,ta) - cf1.$$

Let $Bs = \{b \in WB \mid Pd \text{ is depressed with respect to } b \text{ at time } ta\}$

The intensity of depression of *Pd* at time *ta*:

$$depr(Pd,ta) = \Sigma_{b \in Bs}\, depb(Pd,b,ta).$$

<u>Sadness</u> *Pd* can be sad in the following cases:

i. *Pd* has lost person (or animal), whom he/she loved, for a long time;

ii. *Pd* or person whom *Pd* loves is very sick and will be sick for a long time,

iii. *Pd* has been sent to prison or *Pd* has lost his/her whole property;

iv. *Pd* has concluded that he/she will not be able to perform his/her favourite activity;

v. *Pd* has concluded that he/she cannot achieve his/her important goal.

In order to define sadness, we describe the above formulations more precisely. *Pd* loves an object, *Ol*, if $zulieb(Pd,Ol,ta) > cl1 > 4$ and $abhas(Pd,Ol,ta) < 1$, where $cl1$ is a constant. In this case holds $rosa(Pd,Ol,ta) > cwl$ for a constant cwl (sugg.: $cwl = 50$). Time interval, tr, is a long time if $tr > ct1$, where $ct1$ is a constant depending on *Pd*. Examples: $ct1 = 1$ *week* for an 8 years old child. $ct1 = 1$ *month* for an 12 years old child: $ct1 = 0.5$ *year* for a 20 years old man. '*Pd* has lost an object (*Ol*) or had to separate from this object' means *Pd* has not the satisfactions of the intensity $rosa(Pd,Ol,ta) > cwl$ associated with *Ol*. 'Be very sick or a loved person is very sick' means: *Pd* is in a grave situation *Sw*, i.e. *Pd* perceives negative stimulus of the intensity $rosa(Pd,Sw,ta) < -cwl$. 'Be in prison or lose his/her whole property' means, as above, that *Pd* is in a grave situation *Sw*. (iv) is a case of '*Pd* had to give up activity, *AVl*, such that $rosa(Pd,AVl,ta) > cwl$, i e. *Pd* has not the satisfactions of the intensity $rosa(Pd,AVl,ta)$ associated with the activity *AVl*. '*Pd* cannot achieve his/her important goal situation *Sz*' (case v) means: *Pd* has not and will not have the satisfactions associated with achieving the goal *Sz* and, additional, *Pd* perceives the negative stimuli connected with not achieving the goal *Sz*.

When *Pd* is separated, for a long time, from an object or situation that he/she loves then *Pd* must not be sad. Only when his/her state of emotions is not good, i.e. if $unku(Pd,ta) < ck < 0$, then *Pd* is sad, where $unku(Pd,ta) = \Sigma_{b \in WB}\, zful(Pd,b,ta)$ (sugg : $ck = -8$). On the basis of these observations, we define: *Pd* is sad with respect to *OSA*, at time *ta*, if $unku(Pd,ta) < ck$ and one of the following conditions *trau1*, *trau2*, *trau3* hold:

<u>*trau1*</u>. *Pd* is aware that he/she is separated from *OSA*, in degree $0 < gtr \leq 1.5$ for a time $tr > ct1$, and $rosa(Pd,OSA,ta) > cwl$, where $0.4 < gtr < 1$ if *Pd* is only in letter communication with person *OSA*, $0 < gtr < 0.6$ if *Pd* communicates with *OSA* also by telephone, $gtr = 1.5$ if person *OSA* is dead.

<u>*trau2*</u>. *Pd* is aware, at time *ta*, that he/she is in a grave situation, *Sw*, such that $rosa(Pd,Sw,ta) < -cwl$, and will be in this situation for a time $tr > ct1$.

<u>*trau3*</u>. *Pd* is aware, at time *ta*, that he/she cannot achieve his/her goal situation *Sz* and for the whole stimulus, $grnz(Pd,Sz,ta)$, associated with this fact holds $grnz(Pd,Sz,ta) < -cwl$.

The intensity of sadness of *Pd* with respect to *OSA*, in case *trau1*, at time *ta*:

$$traur1(Pd,OSA,ta) = lnj(tr) * gtr * (ctr1 * rosa(Pd,OSA,ta) - unku(Pd,ta) - cwl * ctr1 + ck)$$

where $lnj(tr) = ln(1-ct1+tr)$ if $ct1 < tr < 30$ *years*, $lnj(tr) = ln(31-ct1)$ if $tr \geq 30$ *years*, $0.1 < ctr1 \leq 1$ (sugg.: $ctr1 = 0.5$).

The intensity of sadness of *Pd* with respect to situation *Sw*, in case *trau2*, at time *ta*:

$$traur2(Pd,Sw,ta) = - lnj(tr) * (ctr1 * rosa(Pd,Sw,ta) + unku(Pd,ta) + cwl * ctr1 - ck).$$

The intensity of sadness of *Pd* when goal situation *Sz* has not been achieved (case *trau3*). First we define the function $grnz(Pd,Sz,ta)$. Because *Pd* does not achieve the goal situation *Sz*, he/she does not perceive the following expected (positive) stimulus of *Sz*:

$$rerz(Pd,Sz,ta) = rosa(Pd,Sz,ta) + \Sigma_{b \in Bz1}\, epr(Pd,Sz,fsp,b,a,ta) - \Sigma_{b \in Bz2}\, enr(Pd,Sz,fsn,b,a,ta)$$

where: *fsp* denotes *epb, upb, epbu, upbu, vnb* and *vpb*, $epr(Pd,Sz,fsp,b,a,ta)$ is defined in Sect. 2.3.1,

$Bz1 = \{b \in WB \mid$ (*'dser'*; (...$fsp(Pd,b)$ =...)) is attached to the situation *Sz* in the list *LZS* $\}$,

$Bz2 = \{b \in WB \mid$ (*'dser'*; (...$fsn(Pd,b)$ =...)) is attached to the situation *Sz* in the list *LZS* $\}$,

fsn denotes *enb, unb, enbu, unbu, vnb* and *vpb*, $enr(Pd,Sz,fsp,b,a,ta)$ is defined in Sect. 2.3.2. Additional, the situation 'the goal *Sz* has not been or will not be achieved' causes the stimulus (in most cases negative):

$$rnez(Pd,Sz,ta) = \Sigma_{b \in Bz3}\, epr(Pd,Sz,fsp,b,a,ta) - \Sigma_{b \in Bz4}\, enr(Pd,Sz,fsn,b,a,ta)$$

where $Bz3 = \{b \in WB \mid$ (*'dsne'*; (...$fsp(Pd,b)$ =...)) is attached to situation *Sz* in the list *LZS*$\}$,

$Bz4 = \{b \in WB \mid$ (*'dsne'*; (...$fsn(Pd,b)$ =...)) is attached to situation *Sz* in the list *LZS*$\}$.

The whole decrease of satisfactions arising from not achieving goal situation *Sz* equals:

$$grnz(Pd,Sz,ta) = - rerz(Pd,Sz,ta) + rnez(Pd,Sz,ta).$$

The intensity of sadness of *Pd* when he/she has not achieved goal situation *Sz* (case *trau3*) equals:

$$traur3(Pd,Sz,ta) = - ctr1 * grnz(Pd,Sz,ta) - unku(Pd,ta) - cwl * ctr1 + ck.$$

<u>Positive and negative feelings to *OSA*</u>. *Pd* has positive emotions to *OSA*, at time *ta*, if $zulieb(Pd,OSA,ta) > 0$. The intensity of these emotions to *OSA* equals $zulieb(Pd,OSA,ta)$. *Pd* has negative emotions to *OSA*, at time *ta*, if $abhas(Pd,OSA,ta) > 0$. The intensity of these emotions to *OSA* equals $abhas(Pd,OSA,ta)$.

<u>Dislike</u>. *Pd* dislikes *OSA*, at time *ta*, if $abhas(Pd,OSA,ta) - 1.2 * zulieb(Pd,OSA,ta) > 1$. The intensity of this dislike:

$$abn(Pd,OSA,ta) = abhas(Pd,OSA,ta) - 1.2 * zulieb(Pd,OSA,ta) - 1.$$

Annoyance. Let OS denotes an object or a situation. Pd is annoyed at/with OS, at time ta, when $1 < abhas(Pd,OS,ta) < car$ and Pd thinks - believes - that he/she can perform activities $AVa1,...,AVak$ which will prevent OS from decreasing $bef(Pd,b,.)$ in future, where $b \in Bd(Pd)$ and car is a constant. The intensity of this annoyance equals $abhas(Pd,OS,ta) - 1$.

Anger. Pd has anger at/with OS, at time ta, when $abhas(Pd,OS,ta) > 0.85 * car$ and Pd thinks - believes - that he/she can perform activities $AVz1,...,AVzk$ which will prevent OS from decreasing $bef(Pd,b,.)$ in future, where $b \in Bd(Pd)$. The intensity of this anger equals $abhas(Pd,OS,ta) - 1$.

Hate. Pd hates OSA, at time ta, if $abhas(Pd,OSA,ta) > 2.5$ and $des(Pd,bvr(OSA),ta) > 2$ ($bvr(OSA)$ - the need for retaliation and revenge on OSA, s. Sect. 5). The intensity of this hate, at time ta, equals

$$has(Pd,OSA,ta) = des(Pd,bvr(OSA),ta) * abhas(Pd,OSA,ta) - 5.$$

6.2. Fear

Pd feels fear when he/she is in one of the following situations $fur1,..., fur3.1$:

fur1. Fear of a situation or an object: Pd perceives situation Sf or object Of in the situation Sf such that:

i. $rosa(Pd,Sf,ta) < - 0.2 * cwl$ and Pd is, will or can be in the situation Sf;

ii. Pd believes that he/she can perform only activity AVf (e.g. 'do nothing') which might, with probability $pv < 0.95$, extricate Pd from the situation Sf.

Example 6.1. The virtual boy $vJ1$ in the entertainment software ESJ (s. Example 2.7, Sect. 2.2) is humiliated by the virtual boy vJg, when they meet (situation Sg). $vJ1$ fears vJg and tries to avoid him. This behavior, Vv, is effective only in $20\ \%$ ($pvj = 0.2$). It holds $rosa(vJ1,Sg,ta) < -20$.

fur1.1. Fear of a decrease of $bef(Pd,b,.)$ ($b \in WB$): Pd believes (or perceives) that $bef(Pd,b,ta)$ will decrease by $fy(b) > 5$ in time $(t1,t2)$ ($t1 \geq ta$). Pd thinks that he/she can perform only activity AVf which would prevent the decrease of $bef(Pd,b,ta)$, only with probability $pv < 0.95$.

Example 6.2. vP is the virtual person in the entertainment software ES (s. Example 2.4, Sect. 2.2). Virtual physician told vP that he/she has cancer, i.e. the values of $bef(vP,GE,ta)$ and $bef(vP,LE,ta)$ will probable decrease according to the patterns $enb(vP,GE)$ and $enb(vP,LE)$ given in Example 2.4. vP fears these decreases of bef and believes that only the behavior, Vas, 'I will do what the virtual doctor $vAKs$ prescribes' (s. Example 2.6) can partially prevent these bef decreases, with probability $pkv = 0.3$.

fur2. Fear of separation from an object or a situation (OSl): $rosa(Pd,OSl,ta) > 0.2 * cwl$ and Pd perceives or believes (time ta) that he/she can be compelled to separate from OSl, in degree $0 < gtr \leq 1.5$, with probability ptr, for a time $tr > ct1$.

fur3. Fear of performing an activity not right or of not achieving goal situation:

i. Let *Sz2* be a goal situation of *Pd*, where *rosa(Pd,Sz2,ta) > 0.2 * cwl*. *Pd* is in a situation *S1* and believes that he/she could achieve situation *Sz2* when he/she would execute activity *AV12*;

ii. However, *Pd* believes that when he/she would execute the activity *AV12* then he/she could achieve, with probability $p12 > 0.1$, an undesirable situation in *SF* instead of the goal situation *Sz2* (e.g. if *Pd* executes *AV12* wrong or *AV12* is not suitable for achieving *Sz2*), where $rosa(Pd,Sf2,ta) \leq r12 < 0.95 * rosa(Pd,Sz2,ta)$ for $Sf2 \in SF$.

Example 6.3. The virtual skier ***vPm*** appearing in the entertainment software *ES1* (s. Example 2 2, Sect 2.2) stands at the top of a steep piste. He never skid over such difficult piste. When he would run well to the bottom of the piste (behavior *Vsf*) then he would achieve his goal situation, *Sgf*, 'I've run well (by ski) to the bottom of the piste and I'm happy`. When ***vPm*** would not run well and fall down then he can be in one of the 3 situations: *Sgu* - 'I've fallen down but I can continue skiing`, . *Ssu* - 'I've fallen down and have pain in the knee, I can't continue skiing but I can walk`, *Ssv* - 'I've fallen down, I'm serious hurt and I can't walk`. ***vPm*** thinks (at time *ta*) that the probability of achieving the situation *Ssu* or *Ssv* equals $psg = 0.2$. It holds $rosa(vPm,Ssv,ta) < 1.8 * rosa(vPm,Ssu,ta) < -60$ and $rosa(vPm,Sgu,ta) > -10$.

fur3.1. A special case of *fur3*: *Pd* achieves either the goal situation *Sz2* or only one undesirable situation *Sf2* (thus $SF = \{Sf2\}$). In this case, the condition (ii) in *fur3* reads as follows:

ii`. *Pd* believes that when he/she executes activity *AV12* then he/she will achieve the undesirable situation *Sf2*, with probability *p12*, and the goal situation *Sz2* with probability $1 - p12$.

Example 6.4. *vPt* is a virtual technician in an entertainment software *ESt*. He is unemployed since 10 months and could not achieve his goal situation, *Sah*, 'have a job according to my qualifications`. He applied many times for a job (behavior *Vbew*) but received only negative answers (situation *Sar* - 'continuation of his unemployment`). His hope (*pa*) of getting a job decreased from *0.95* (before 10 months) to *0.3* now (time *ta*), i.e. *vPt* believes that, with probability $1 - pa = 0.7$, also the next answers to his applications will be negative. *vPt* fears these negative answers - he is in fear of the situation *Sar* and he fears that he does not achieve his goal *Sz2* by the behavior *Vbew* .

fur1.1 is a special case of *fur1* because every decrease of *bef(Pd,b,.)* can be considered as a situation *Sf* in which the pattern *('ds`;...fsn(Pd,b) = ...)* occurs which describes this decrease of *bef(Pd,b,.)*. Therefore, we give the intensity of fear only for cases *fur1*, *fur2*, *fur3* and *fur3.1*.

The intensity of the fear described in *fur1*·

(6.1) $$furh(Pd,Sf,AVf,ta) = - (1 - pv) * rosa(Pd,Sf2,ta).$$

In Example 6.1, the boy *vJ1* fears the situation *Sg* (to meet the boy *vJg*). The intensity of this fear equals

$furh(vJ1,Sg,Vv,ta) = -(1 - pvj)*rosa(vJ1,Sg,ta)$. In Example 6.2, vP fears the situation, Skk, 'have cancer'. The intensity of this fear equals $furh(vP,Skk,Vas,ta) = -(1 - pkv)*rosa(vP,Skk,ta)$.

In order to define the intensity of the fear described in *fur2*, we must notice the following: Pd thinks (at time ta) that he/she will be in situations Slj, in time $(ta,ta+tr)$, $j = 1,\dots,k$, such that: (i) Pd has a situation model $SMlj$ of the situation Slj, where $SMlj$ differs from $SMlr$ for $j \neq r$; (ii) when Pd is in situation Slj (at time tj, $ta < tj < ta+tr$) and is separated from OSl in degree gtr then $rosa(Pd,OSl,tj) > 0.2*cwl$, for $j=1,\dots,k$. If Pd does not imagine such situations then $k=0$. Let $Slj1,\dots,Sljm$ are the situations which have the greatest values $rosa(Pd,OSl,tje)$ (where $m<5$), i.e. $rosa(Pd,OSl,ti) \leq min(rosa(Pd,OSl,tje),\ 1 \leq e \leq m)$ for $i \neq je$ and $e \leq m$. The intensity of the fear of separation from OSl, when Pd imagines that he/she would be in situations $Sl1,\dots,Slk$, after the separation, equals:

(6.2) $$furv(Pd,OSl,ta) = ptr*gtr*(rosa(Pd,OSl,ta) + rosa(Pd,OSl,tj1) + \dots + rosa(Pd,OSl,tjm)).$$

The intensity of the fear described in *fur3*:

(6.3) $$angs(Pd,SF,AV12,ta) \geq p12*(rosa(Pd,Sz2,ta) - r12).$$

The intensity of the fear described in *fur3.1*:

(6.4) $$angs(Pd,SF,AV12,ta) = p12*(rosa(Pd,Sz2,ta) - rosa(Pd,Sf2,ta)).$$

In Example 6.3, the skier vPm fears the situations Ssu and Ssv. The intensity of this fear equals $angs(vPm,\{Ssu, Ssv\},Vsf,ta) \geq 0.2*(rosa(vPm,Sgf,ta) - rosa(vPm,Ssu,ta))$. In Example 6.4, vPt fears the situation Sar (negative answers to his applications). The intensity of this fear equals $angs(vPt,Sar,Vbew,ta) = 0.7*(rosa(vPt,Sah,ta) - rosa(vPt,Sar,ta))$.

7. Envy, Jealousy, Shame and Feeling Guilt

7.1. Envy

A success or a property of a human, $P1$, can be the envy of another human, Pm. A success of $P1$ means an increase of $bef(P1,b1,.)$ for at least one $b1$. A property of $P1$ arises envy of Pm when Pm thinks that $bef(P1,b2,.)$ should be smaller, where $b2$ is associated with this property. Thus, we may define envy more precisely as follows: A human Pm envies human $P1$ his/her success or property, at time ta, when Pm believes that:

- $bfm(P1,b,ta) \geq cn(b) + bef(Pm,b,ta)$, for at least one $b \in Bd(Pm)$, where Pm thinks that the value $bef(P1,b,ta)$ equals $bfm(P1,b,ta)$ and $cn(b) \geq 0$;
- Pm thinks that $P1$ has no right to such great value $bfm(P1,b,ta)$.

With this envy of Pm is connected the following need of Pm:

$bnd(b)$ - $P1$ should have such value $bfm(P1,b,t)$ that $bfm(P1,b,t) < cn(b) + bef(Pm,b,t)$, for $t > ta$. The intensity of the envy of Pm at the value $bfm(P1,b,ta)$ is described by $bef(Pm,bnd(b),ta)$ and $des(Pm,bnd(b),ta)$ as follows:

$$bef(Pm,bnd(b),ta) = min(bef(Pm,b,ta) + cn(b) - bfm(P1,b,ta) + 15,\ 15),$$

$$des(Pm,bnd(b),ta) = max(ch1*(bfm(P1,b,ta) - cn(b) - bef(Pm,b,ta)),\ 0),$$

where $1 < ch1 < 2$ (sugg.: $ch1 = 1.4$).

7.2. Jealousy

A human or a mammal, *Pd*, is jealous of an object, *Of*, when *Pd* believes that he/she must share his/her kind feeling, friendship or love for a human or a mammal, *Pd1*, with the object *Of*, or he/she is losing the positive emotions of *Pd1* towards *Pd* because of the positive feeling of *Pd1* towards the object *Of*. *Pd* and *Pd1* may be agent systems if they simulate emotions. We defined the intensity of friendship and love of *Pd* towards an object *Ob* as *zulieb(Pd,Ob,ta)*. By this function we define jealousy more precisely as follows: *Pd* is jealous of an object, *Of*, (at time *ta*) because of kind feeling, friendship or love of *Pd1* towards *Of* when:

- $zulieb(Pd,Pd1,ta) > 1$ and *Pd* believes that *zuliew(Pd1,Pd,ta)* has decreased or is going to be decreased because *zuliew(Pd1,Of,ta)* is too great or is going to be too great, where *zuliew(Pd1,Pd,ta)* and *zuliew(Pd1,Of,ta)* are the values *zulieb(Pd1,Pd,ta)* and *zulieb(Pd1,Of,ta)*, respectively, as they are perceived by *Pd*;
- *Pd* does not accept the positive feelings of *Pd1* towards *Of*, i.e *Pd* does not accept the intensity *zuliew(Pd1,Of,ta)* and the perceived or expected decrease of *zuliew(Pd1,Pd,ta)*, in degree $0 \leq anl(Pd1,Of,ta) \leq 1$.

With this jealousy of *Pd* is connected the following need of *Pd*:

beif(Of) - decrease *zuliew(Pd1,Of,ta)*. The intensity of this jealousy is given by

$$bef(Pd,beif(Of),t) = max(-22,\ 6 - sqrt(sqrt(zuliew(Pd1,Of,ta) * zulieb(Pd,Pd1,ta) * 0.5)) * anl(Pd1,Of,ta))$$

$$des(Pd,beif(Of),t) = min(55,\ ch1 * (6 - bef(Pd,beif(Of),t))).$$

7.3. Shame and Feeling Guilt

Let *NG* denotes the set of norms and rules of *Pd* or the community to which *Pd* belongs. For example, some goals and ethical principles which *Pd* fixed for himself We assume that *Pd* accepts the norms and rules in *NG* and has needs, *bnr(uNe)*, to fulfil the norms and rules in $uNe \subset NG$, where the sum of subsets *uNe* equals *NG* and $uNe \cap uNj = \varnothing$. The need *bnr(uNe)* is a special case of the need *AN* (recognition, acknowledgment and self-esteem) Thus, if *Pd* does not fulfil some norms in *NG* then *bef(Pd,AN,.)* and *zful(Pd,AN,.)* decrease.

Shame. *Pd* has shame (at time *ta*) when.

i. *Pd* has violated some norms or rules in *NG*, or *Pd* could not fulfil some norms or rules in *NG* (e.g. *Pd* has been forced to do something against these norms and rules);

ii. because of (i), *zful(Pd,AN,ta)* decreased by $dzf(AN) > 1$;

iii. *Pd* cannot perform any activity which would increase *zful(Pd,AN,ta)* by $dsl(AN) > 0.4 * dzf(AN)$.

The intensity of this shame is given by:

$$sha(Pd,ta) := sha(Pd,ta) + dzf((AN).$$

The initial value of *sha(Pd,.)* equals *0*. When *zful(Pd,AN,t)* increases by $df(AN) > 0.4$ then *sha(Pd,.)* decreases:

$$sha(Pd,t) := sha(Pd,t) - cs1 * df((AN)$$

where $0 < cs1 < 1$ (sugg. $cs1 = 0.7$). However, *Pd* has in his/her memory the situation, *Sh*, which caused the shame. When *Pd* imagines the situation *Sh* (at time $t1 > ta + 1\ day$) then *Pd* feels again the shame connected with the situation *Sh*. The intensity of this shame equals $cs2 * sha(Pd,ta)$ where $0 < cs2 \leq 1$ and *cs2* expresses the intensity of the imagination of the situation *Sh*.

Feeling guilt. There are several opinions about what emotion is feeling guilty (s. Izard [IZA], (1994)). The definition given below reflects the basic ideas of these opinions. Let *PO* denotes God, deity, ghost, human, animal, a group of persons or animals (e.g. a community), organization, institution; *PO* can be also *Pd*.

Pd feels guilty with regard to *PO*, at time *ta*, when:

i. *Pd* performed activities *AVs1,...,AVsu* (in time *(ta-vt-wt, ta-vt)*, where $vt \geq 0$, $wt > 0$) which did damage to *PO* (e.g. injured *PO*) although *Pd* could perform other activities which had done only little or no damage to *PO*;

ii. *Pd* is conscious (at time *ta*) that: (a) he/she failed - he/she violated some norms or rules in *NG* - when performing the activities *AVsi*, $i=1,...,u$, (b) he/she has positive feelings towards *PO*.

This description we state more precisely: *Pd* feels guilty with regard to *PO*, at time *ta*, when:

s1. *Pd* performed activities *AVs1,...,AVsu* (in time *(ta-vt-wt, ta-vt)*, where $vt \geq 0$, $wt \geq 0$) which did damage to *PO* - *Pd* is aware (at time *ta*) that he/she decreased *bef(PO,b,ta-vt-wt)* by *dos(b)* for $b \in Bo$; if *Pd* had performed these activities in a better way or instead of *AVsi* had performed other activities, then *Pd* would have done only little or no damage to *PO*;

s2. *Pd* is conscious (perceives, at time *ta*) that: (a) because of his/her activities *AVsi*, $i=1,...,u$, and his/her failure (in the time *(ta-vt-wt,ta-vt)*), *zful(Pd,AN,ta)* decreased by *dfv(AN)*, (b) $zulieb(Pd,PO,ta) - abhas(Pd,PO,ta) > 0.2$.

The intensity of feeling guilt with regard to *PO*, at time *ta*, equals:

$$shuld(Pd,PO,ta) = (zulieb(Pd,PO,ta) - abhas(Pd,PO,ta)) * dfv(AN) * sqrt(scha(PO))$$

where $scha(PO) = \Sigma_{b \in Bo}\ dos(b)$

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Claims to

Representation of Emotions in Electronic Devices

Schurmann Alfred

Claim 1. Representation of stimulus patterns in descriptions of objects, situations and activities The form of said stimulus patterns. The method for determining intensity of expected satisfaction (*bef(Pd,b,ta+i*q)*) and expected desire (*des(Pd,b,ta+i*q)*), with respect to a need *b*, by these stimulus patterns. The use of said stimulus patterns to:

* determination of intensity of expected stimulus of an object, of a situation or of an activity (*OSA*);
* representation of intensities of the emotions: contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering;
* representation of intensity of expected contentment and joy when achieving of a goal is realized;
* representation of intensity of dissatisfaction, disappointment and anger when obstacles make difficult to realize achieving a goal (a goal situation) or when a goal has not been achieved;
* representation of intensities of positive emotions (liking, friendship, affection, love) and negative emotions (dislike, annoyance, anger, hate) to/for an object, a situation or an activity *OSA*;
* representation of intensities of the emotions: desire for retaliation and revenge, frustration, depression, sadness, fear, hate, envy, jealousy, shame and feeling guilt.

Claim 2 The method for representing intensities of the emotions (with respect to a need *b*): contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering - it includes:

* the intensities of these feelings of *Pd* (at time *t*) are given by function values (e g by *zful(Pd,b,t)*), where *Pd* denotes a human, a mammal, a virtual human or mammal in a software system, or an agent system (e.g. a robot);
* the intensities of said emotions change when: (i) *Pd* perceives values of satisfactions (*bef(Pd,b,ta)*) and desires (*des(Pd,b,ta)*) by senses or sensors, (ii) *Pd* perceives an object, a situation, or an activity (*OSA*), (iii) *Pd* perceives that he/she is achieving his/her goal situation or that he/she cannot achieve the goal situation;
* said, in Claim 1, stimulus patterns are associated with a goal situation, in the list of current goals;
* representation of intensity of contentment and joy when *Pd* realizes achieving a goal;
* representation of intensity of dissatisfaction, disappointment and anger when obstacles make difficult to realize achieving of a goal situation or of an intermediate goal, or when *Pd* has not achieved his/her goal.

Claim 3. The method for representing intensities of positive emotions (liking, friendship, affection, love) (e.g. by *zulieb(Pd,OSA,t)*) and negative emotions (dislike, annoyance, anger) (e.g. by *abhas(Pd,OSA,t)*) to/for an object, a situation or an activity (*OSA*) - it includes:

- the intensities of said emotions are determined by said, in Claim 1 and 2, intensities of satisfaction (*bef(Pd,b,t)*) and desire (*des(Pd,b,t)*);
- the intensities of said emotions change when *Pd* perceives that: (i) said *OSA* caused, supported or prevented an increase or decrease of intensities of satisfaction (*bef(Pd,b,t)*) or desire (*des(Pd,b,t)*); (ii) *OSA* realized, supported or prevented achieving a goal (a goal situation).

Claim 4. The method for representing intensity of desire for retaliation and revenge on an object (*Ob*) - it includes:

- said intensity of desire for retaliation and revenge change when said, in Claim 3, intensities of negative or positive emotions to/for said *Ob* increase or decrease;
- the intensity of said feeling is determined by said, in Claim 3, intensity of negative emotions to said *Ob*.

Claim 5. The method for representing intensities of the emotions frustration and depression - it includes:

- intensities of said emotions are determined by: (i) said, in Claim 2, intensities of contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering; (ii) said, in Claim 1, intensity of stimulus of an object, of a situation or of an activity, *OSA*.

Claim 6. The method for representing intensity of hate to an object *Ob* - it includes:

- said intensity of hate is determined by: (i) said, in Claim 3, intensity of negative emotions (e g by *abhas(Pd,Ob,t)*) to/for said *Ob;* (ii) said, in Claim 4, intensity of desire for retaliation and revenge on said object *Ob*.

Claim 7. The method for representing intensity of sadness - it includes:

- said intensity of sadness is determined by: (i) said, in Claim 2, intensities of contentment, joy, happiness, dissatisfaction, annoyance, anger, grief, pain and suffering; (ii) said, in Claim 1, intensity of stimulus of an object, of a situation or of an activity, *OSA*.

Claim 8. The method for representing the intensity of fear - it includes:

- said intensity of fear is determined by said, in Claim 1, intensity of stimulus of an object, of a situation or of an activity, *OSA*.

Claim 9. The method for representing the intensity of envy - it includes:

- said intensity of envy is determined by said, in Claim 1 and 2, intensity of satisfaction (*bef(Pd,b,t)*) or desire (*des(Pd,b,t)*).

Claim 10. The method for representing the intensity of jealousy - it includes:

- said intensity of jealousy is determined by said, in Claim 3, intensities of the feelings liking, sympathy, friendship and love to/for an object *Ob* (e.g. by *zulieb(Pd,Ob,t)*).

Claim 11. The method for representing the intensity of shame - it includes:

* said intensity of shame is determined by said, in Claim 2, intensity of the emotions dissatisfaction, annoyance, anger, grief, pain and suffering (e.g. by *zful(Pd,AN,t)*), with respect to the need (*AN*) 'for recognition, acknowledgment and self-esteem`.

Claim 12. The method for representing the intensity of feeling guilt - it includes:

* said intensity of feeling guilt is determined by: (i) said, in Claim 2, intensity of the emotions dissatisfaction, annoyance, anger, grief, pain and suffering (e.g by *zful(Pd,AN,t)*), with respect to the need (*AN*) 'for recognition, acknowledgment and self-esteem`; (ii) said, in Claim 3, intensities of positive emotions (e.g. *zulib(Pd,PO,t)*) and negative emotions (e.g. *abhas(Pd,PO,t)*) towards an object *PO*; (iii) said, in Claim 1 and 2, intensity of satisfaction (*bef(Pd,b,t)*) or desire (*des(Pd,b,t)*).

Abstract of

Representation of Emotions in Electronic Devices

Schurmann Alfred

A new, formal representation of emotion states in electronic devices (e g in software systems and mobile agent systems) is described. This emotion representation is based on the notions: intensities of satisfaction and desire, for a need. This representation enables good simulation of emotions in entertainment software and (mobile) agent systems.

There are given conditions for changes of intensities of main emotions, based on the notions satisfaction and desire, and the given stimulus patterns. Let *OSA* be a description (a model) of an object, of a situation or of an activity. Intensities of the following emotions are determined by formulae:

- contentment, joy, happiness, dissatisfaction, annoyance, grief, anger, sadness, pain and suffering;
- positive emotions (liking, affection, love) and negative ones (dislike, annoyance, anger) to/for *OSA*;
- satisfaction and joy when a goal (i e goal situation) is achieved; dissatisfaction, annoyance and disappointment when a goal situation is not achieved;
- desire for retaliation and revenge, hate to an object;
- frustration, depression, sadness, envy, jealousy, shame and feeling guilt.

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PTO/SB/01 (10-00)
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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☒ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	
First Named Inventor	Schurmann
COMPLETE IF KNOWN	
Application Number	PCT/DE 00/03210
Filing Date	Sept. 14, 2000
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) ~~or an original, first and joint inventor~~ ~~(if~~ plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Representation of Emotions in Electronic Devices

(Title of the Invention)

the specification of which

☒ is attached hereto

OR

☒ was filed on (MM/DD/YYYY) Sept. 14, 2000 as ~~United States Application Number or~~ PCT International Application Number PCT/DE 00/03210 and was amended on (MM/DD/YYYY) ____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR : ☐ A petition has been filed for this unsigned inventor

1-00

Given Name (first and middle [if any]) Alfred		Family Name or Surname SCHURMANN	
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Inventor's Signature		Date	
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City	State	ZIP	Country

☐ Additional inventors are being named on the ___ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto.

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STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR	Docket Number (Optional)

Applicant, Patentee, or Identifier: Alfred SCHURMANN

Application or ~~Patent~~ No.: PCT/DE00/03210

Filed ~~or Issued~~: September 14, 2000

Title: Representation of Emotions in Electronic Devices

As a below named inventor, I hereby state that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- [ ] the specification filed herewith with title as listed above.
- [x] the application identified above.
- [ ] the patent identified above.

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Separate statements are required from each named person, concern, or organization having rights to the invention stating their status as small entities. (37 CFR 1.27)

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A. Schurmann NAME OF INVENTOR	NAME OF INVENTOR	NAME OF INVENTOR
A. Schurmann Signature of inventor	Signature of inventor	Signature of inventor
March 19, 2002 Date	Date	Date

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